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INDIA

Part I

PHYSICAL BASIS OF GEOGRAPHY OF INDIA

By

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Dedicated
to
Sir S. Radhakrishnan,
Vice-Chancellor, Benares Hindu University

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INDIA

Part I

PHYSICAL BASIS OF GEOGRAPHY OF INDIA

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PREFACE

It need hardly be emphasized that a knowledge of the physical basis of geography of a country is indispensable not only for the proper grasp of its geography as a whole, but also for the understanding of its economic development. The climate of a country is determined to a large extent by its physical features; and the climate itself, in turn, is responsible for the main agricultural, forest and animal products. These comprise the raw materials upon which the development of industries depends. It affects, in fact, every activity of man. I cannot do better than quote the words of the veteran physical geographer, the late Sir Archibald Geikie: "Geographers are too apt to forget that in order to understand the geography of any region, as it now is, we must learn how it has been gradually built up. No country came into existence as it now is. If we would discover how its topography has originated, we must study the results of long continued geological observation."

The physical basis of geography of India is often dismissed in a few paragraphs even in books which deal fully with other aspects of the subject. In fact, the somewhat inadequate teaching of the subject in schools and colleges has also doubtless been due to the want of a suitable manual. At present the information has to be collected piecemeal, a task much beyond the diligence of an average student. Not infrequently the really important information is buried on the shelves of some libraries. To supply that want, I have laboured to produce this treatise.

Some portions of the book have been written mainly from personal observation. However, I have drawn freely from the previous literature. In a conspectus of this kind it is almost impossible to thank every one individually.

I therefore offer my heartiest thanks to all those whose work I may have used in the publication of this work.

It was originally intended to publish the work in one volume but owing to my transfer to Lucknow, some delay was caused in its publication. It was, therefore, deemed advisable to issue the Physical Basis of Geography of India, which had already been composed, as Part I of the work. Thus it was also rendered possible to give a fuller treatment to the fundamental basis of the geography of India.

In the spellings of place names and other localities I have followed Reference Index—"Where is it" issued by the Survey of India.

It has been a great pleasure to dedicate this treatise to Sir Sarvpalli Radhakrishnan, Vice-Chancellor, Benares Hindu University for his very eminent services to the cause of education in India and abroad and to the service of humanity in general. Likewise I am also indebted to Mr. Rang Behari Lal, Pro-Vice Chancellor, Benares Hindu University for his warm sympathy and blessings.

I take this opportunity of tendering my best thanks to the authorities of the Bombay Natural History Society for the loan of five blocks four out of which have been used in this book.

Finally I express my best thanks to Mr. S. P. Dey of the Pioneer Press for kindly evincing interest in the printing of the book.

H. L. CHHIBBER.

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CHAPTER I

PHYSICAL DIVISIONS OF INDIA

Position and Extent

India occupies an almost central position in the Eastern Hemisphere. It has a length and breadth of about 2,000 miles in each direction. From south to north it extends from 8° North latitude to 37° North latitude. It extends from about 62° East longitude to 97° East longitude. In the north, the great Himalayas stretch from Kashmir to Assam. It forms a peninsula with a coastline of about 4,000 miles and has some great seaports.

It occupies an area of 1,631,501 square miles and represents the largest country in Asia and one of the largest in the world. It has a population of 388·8 millions, which forms nearly one-fifth of the total population of the world. In British India, excluding the Native States, there are 680 million acres of land, of which 40 per cent. is cultivated. Out of this, 18 per cent. receives the benefit of irrigation.

Physical Features

As the physical features of a country determine mainly the climate, crops, other economic products, occupations and distribution of man, development of industries and transport, a detailed account of the important physical features is given.

Physical Divisions

India can be divided into four physical regions, each having its own physiographic and economic features (Fig. 1) :—

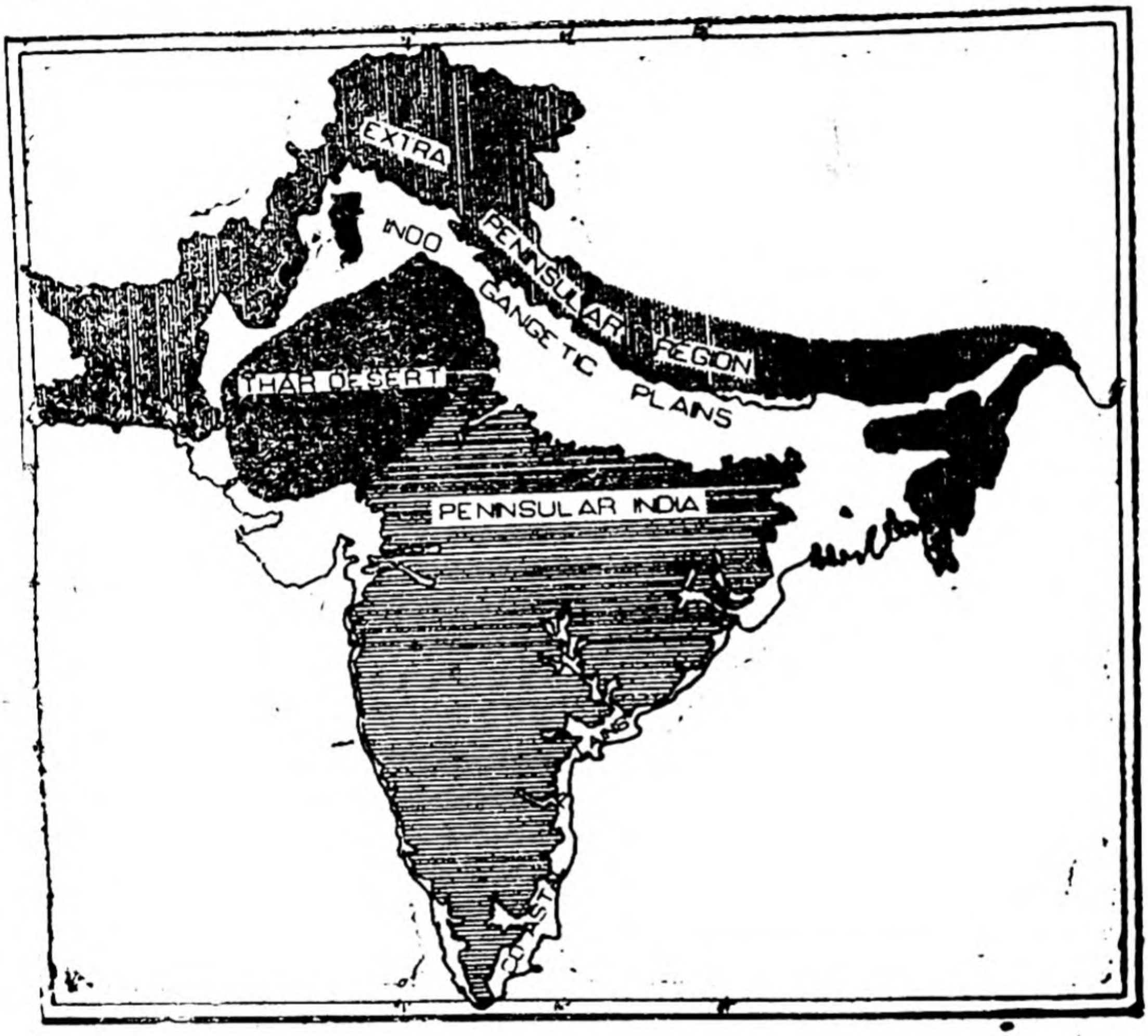


Fig. 1—Showing Physical Divisions of India.

(1) The Plateau of the Deccan or the Peninsular India.

(2) The plains of the Indus, Ganges and the Brahmaputra.

(3) The Himalaya mountains or the Extra Peninsular region.

(4) The Thar Desert.

(1) **The Peninsular Region :**—It is composed chiefly of the gneisses and schists and unfossiliferous sediments which were laid down in the early ages (Archæan Era) of

the earth's history. Except for a few transgressions of the sea, this region has been a land-mass ever since its formation. It is noteworthy that the Peninsular region constitutes what is known as a horst, and has been a very stable portion of the earth's crust which has not been affected by any important movements of folding and faulting. They have only undergone vertical up and down movements as a result of which blocks of more recent coal-bearing sedimentary rocks have been let down in the ancient rocks.

It is very remarkable that the mountains of Peninsular India are just the raised portions of the plateau, which have withstood the wear and tear of the land. The Western and the Eastern Ghats, the Nilgiri, the Anaimalai and the Cardamom hills are examples of hills and mountains formed in this way. Such mountains are called *relict* type of mountains, as they are just relics of the old, once much loftier land-masses.

The rivers, again, are very old which have already reached their base level of erosion. These rivers have little power of vertical erosion but can only perform lateral erosion, *i.e.*, they meander from side to side and can only erode their banks.

The plateau of the Deccan ranges in altitude from about 1,500 feet to about 2,500 feet above sea level, although some of the highest portions attain elevations of over 8,000 feet above sea level.

The plateau is fringed by coastal plains both on the east and the west; those on the east being broad with the deltaic regions of the rivers which have built them. The coastal fringe on the west is, however, narrow as the mountains come close to the sea. The plateau is tilted towards the east; the important rivers therefore flow in that direction.

(2) **The Indo-Gangetic Plains**:—A section drawn from north to south would illustrate the nature of this region. It is really a depression between the Himalayas and the Deccan plateau. It has been filled with alluvium brought down by the rivers from the mountainous region behind. It is believed that when the Himalayas were uplifted into an arch, the site of the Indo-Gangetic plains was depressed into a trough. Some authors, however, have regarded it as a deep rift valley bounded by parallel, vertical faults or dislocations on either side.

Geographically, this is the most interesting and important region. The alluvial land of these plains constitutes one of the most extensive and fertile plains in the world. The plain area in the provinces of Assam, Bengal, Bihar and Orissa has been the home of cultivation of rice and jute, while farther up in the United Provinces, the Punjab and Sind, wheat and cotton with some rice are the most important crops. The alluvial soil of these plains is being cultivated from time immemorial and yet it shows little signs of exhaustion.

(3) **The Extra Peninsular or the Himalayan Region**:—This region has been under the sea during the whole of the early (Palæozoic), the middle (Mesozoic) and some part of the later (Tertiary) ages of the earth's history. This sea, the Tethys of geologists, extended from the Mediterranean to beyond the present site of the Himalayas, which first emerged from the bed of the sea during the early part of the later ages (Tertiary Era) of the earth's history. Undoubtedly, the Himalayas have been subjected to very severe crustal deformation as the strata are very highly folded, faulted and contorted. In other words, the Himalayas are only a great link in the chain of young fold mountains which stretch from Burma, India, Afghanistan, Iran, etc. to the European Alps.

The rivers of the Himalayas are rapid torrential streams which are cutting their channels at a very rapid pace and are still in an immature state of development. The rivers, just before leaving the Himalayas, where they follow a transverse course to the mountains, have carved very deep gorges, thousands of feet in depth.

(4) **The Thar Desert :**—The Thar desert, which occupies a very large part of Rajputana and Sind, has no high hills to intercept the south-west monsoons which pass over them. Consequently, the rainfall of this region is very scanty, amounting from 5 to 10 inches a year.

Structurally, this region exhibits characteristics intermediate between the Deccan and the Himalayan region. The rocks, as in the case of the plateau of the Deccan, show only a little disturbance but marine fossiliferous rocks belonging to the middle (Mesozoic) and later (Tertiary) ages of the earth's history, which are seen only in the Himalayan region, are also present. But as shown later on Rajputana has undergone more severe earth-movements as compared to the stable Peninsular India (*vide* Chapter XX). It is, therefore, obvious that the desert region, both physically and structurally, constitutes a distinct region with characteristics of its own.

CHAPTER II

MOUNTAINS

The mountains of India can be divided into (i) mountains of Peninsular India and (2) mountains of the Extra Peninsular Region. As mentioned in the foregoing chapter their mode of origin is absolutely different.

Mountain Ranges of Peninsular India

The mountain ranges of Peninsular India comprise the following :—

(1) The Ghats, *viz.*, the Western and the Eastern,

(2) Aravalli mountains,

(3) The Vindhyas,

(4) The Satpuras.

Western Ghats :—The Ghats bound India both on its western and eastern coasts. The Western Ghats flank its western shores and run in an unbroken range of hills to the south of Malabar, where they merge with the Nilgiris. Their mean elevation is 3,000 feet above sea level and are formed of the Deccan lavas (the Deccan Trap) which poured forth over nearly half a million square miles towards the close of the middle ages (Mesozoic Era) or about the beginning of the later ages (Tertiary Era) of the earth's history or about the same time when the Himalayas were first uplifted from the bed of the sea. These hills present a "ghat-like" or landing stair aspect and build flat-topped hills so commonly seen in the Central Provinces and elsewhere.

The Western Ghats have a very important influence on the climate of the western shores of India. They help

to precipitate most of the moisture present in the south-west monsoons blowing from the Arabian Sea during summer. Consequently, this coast has very heavy rainfall and its forests therefore are evergreen. The plateau of the Deccan, which is situated on the leeward side, receives much less rainfall, just enough in places to support (Savannah type of) grasslands.

Eastern Ghats:—The Eastern Ghats flank the eastern or Carnatic coast of India and are a much lower range of hills which are broken in places and are irregular. These, unlike the Western Ghats, have a broad coastal plain fringing the hills. This lowland region is, however, very fertile where groundnuts, rice, cotton, tobacco and other crops are grown successfully. In fact, this plain is mainly responsible for the prosperity of the provinces of Madras and Orissa.

Aravalli Mountains:—The Aravallis are true fold mountains which were upheaved in the early ages of the earth's history. They run in a north-easterly direction for about 400 miles in Rajputana. Their general elevation ranges from 1,000 to 3,000 feet above sea level; the highest peak is Mount Abu, 5,650 feet above the sea, which lies at the south-west extremity. These hills are practically bare and very sparsely populated. Large areas, *i.e.*, the intervening valleys are covered with sand deposits. Rocky ridges are to be seen in the States of Alwar, Jaipur, etc. Their northernmost extension is to be found in the low isolated quartzite hills seen in the neighbourhood of Delhi.

The Vindhyas:—The Vindhyas form an interrupted range of hills, 2,500 to 4,500 feet in elevation. They also form the northern part of the Central Provinces and separate the Gangetic basin from the plateau of the Deccan.

On the west they rise in Gujarat and fringe the southern edge of the Malwa plateau. They extend further in the Kaimur range and terminate in the Ganges valley near Benares.

They are composed mainly of sandstones of red and other colours, which are so largely used in architectural works, both large and small, in India. The beds are very little disturbed; in places they are almost horizontal.

The Satpuras:—The Satpuras literally mean seven folds and they form a system of hills between the Tapti and Narbada rivers in Central India. The lofty plateau of Amarkantak is the starting point and the range continues westward almost to the west coast. The average altitude is about 2,500 feet above sea level, but the plateau of Amarkantak is about 3,500 feet above sea level. Some of the peaks, however, are even higher in altitude. The railway from Bombay to Jubbulpore runs through a break in the range just east of the famous hill fortress of Asirgarh, the range here being only 1,240 feet above sea level. The Satpuras have a length of about 600 miles. They are composed partly of the Deccan Trap lavas and partly of granite, etc.

The Himalaya Mountains

It has been mentioned above that starting from the Naga and Lushai Hills in the east and ending in the Baluchistan range of hills on the west is indeed one mighty chain of mountain ranges.

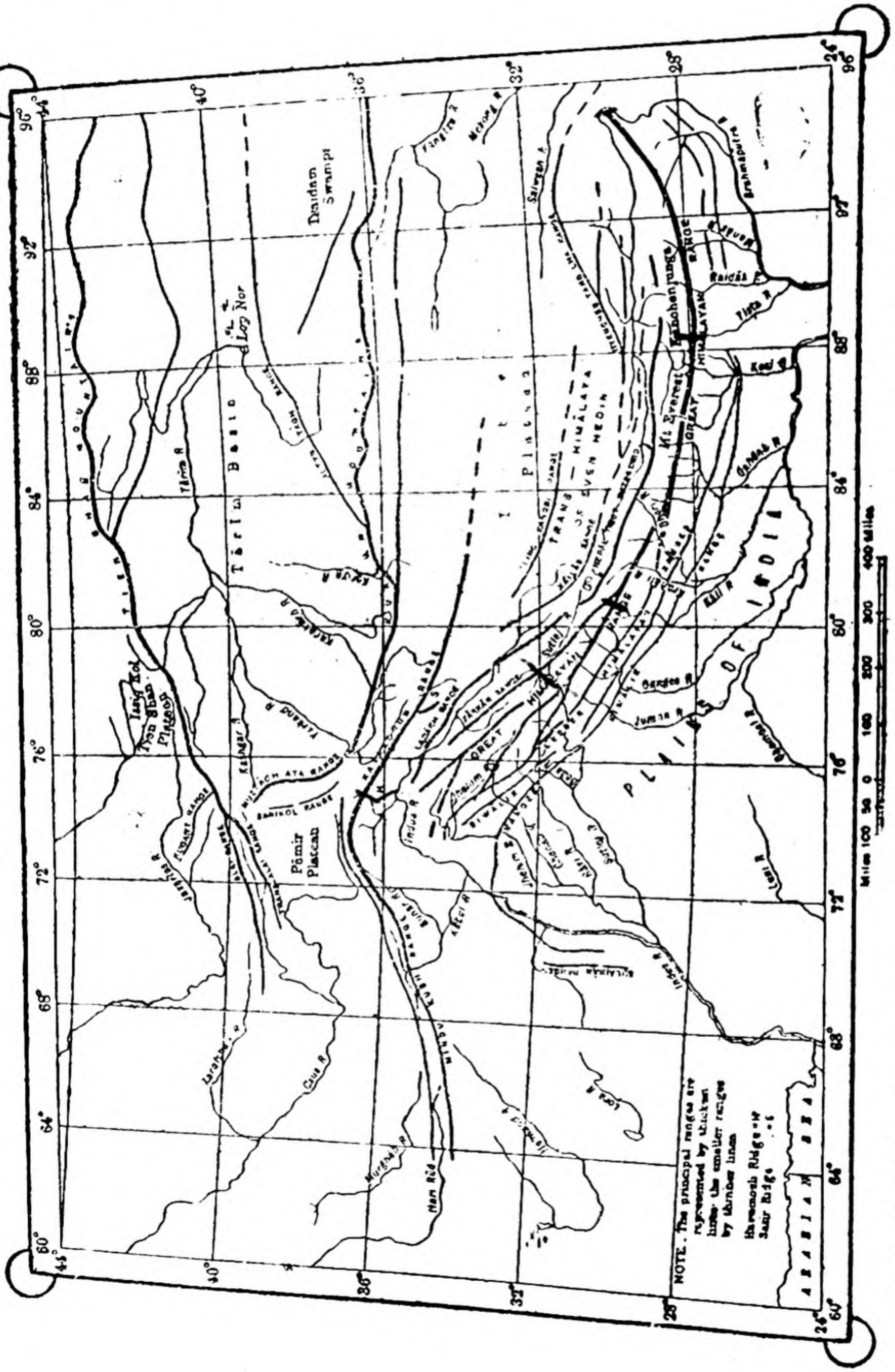
The Himalayas are not a mountain chain in the ordinary sense of the word. Immediately to the north of the plains of India, there rise the highest ranges of the world. The southern portion of this mass is represented by the Himalayas, while the Keunlun (Kunlun) represents its northernmost range. In between these mountains is enclosed the

bleak plateau of Tibet, about 15,000 to 16,000 feet above sea level. It may be noted that neither the Himalayas nor the Kunlun are separated from the plateau of Tibet, but they form one great tangle of mountain masses, which cover in Central Asia an area of one million square miles with a width exceeding 500 miles.

The configuration of the Himalayan ranges would be best understood by a reference to the physical map of Asia. They have an east-west extension in the Darjeeling-Nepal region, but on either side the strike of the mountain changes. Towards the east the ranges assume an east-north-easterly or a north-easterly direction, while towards the west they have a west-north-westerly trend followed by a north-westerly curve. Beyond the Indus valley the mountain chain bends towards the south-west in the North-West Frontier Province, Sind and Baluchistan. The side facing India is convex and the main chain sends off minor ranges which first follow the original direction of the mountain and gradually assume a parallel course to that of the main range.

The Himalayas proper are a mighty chain over 2,000 miles in length and 150 to 200 miles in breadth. It has already been remarked that this chain of mountains was first upheaved towards the beginning of the later ages (Eocene period of the Tertiary Era) of the earth's history. These mountains were raised by stresses acting from the Tibetan plateau in the north. The slopes of the mountains facing the plains are therefore steep, while those facing Tibet are gentle. These stresses in the form of waves were checked by the Deccan plateau, the Aravallis and the Salt Range. These ranges in fact have been responsible for the bending of the Himalayas. Our knowledge of these mountains is still very imperfect although in recent years

the various Everest and other expeditions have greatly helped in unravelling the geography and the history of their formation.


Tarim Basin
Lop Nor
Desert
Plateau
Pamir Plateau
Mt. Everest
Kanchenjunga
Nanga Parbat
Tibet
Kashmir
Nepal
Assam
Bhutan
Sikkim
Ganges R.
Indus R.
Brahmaputra R.
Yangtse R.
Mekong R.
Salween R.
Irrawaddy R.
Tsangpo R.
Karakoram Range
Himalaya
Great Himalayan Range
Trans Himalaya
Plains of India
Arabian Sea
Bay of Bengal
Aksai Chin
Kunlun Mts.
Tsaidam Swamp
Takla Makan Desert
Kara Kash R.
Yarkand R.
Shyok R.
Gilgit R.
Jhelum R.
Sutlej R.
Kosi R.
Gandak R.
Gogra R.
Jumna R.
Chambal R.
Son R.
Narbada R.
Tapti R.
Godavari R.
Krishna R.
Kaveri R.
Mahanadi R.
Kistna R.
Pennar R.
Palar R.
Vaigai R.
Cauvery R.
Periyar R.
Pambar R.
Kalinadi R.
Sharavati R.
Netravati R.
Bharathapuzha R.
Ponnani R.
Kabbani R.
Vaippar R.
Vaigai R.
Tambraparni R.
Kalidas
Tista

To face page 11.

Plate I

A typical view of the Himalaya at the edge of the tree line. *(By the courtesy of the Bombay Natural History Society).*

In general, the Himalayas are a series of parallel but converging ranges intersected by valleys and big plateaux (Fig. 2). It is noteworthy that the Eastern Himalayas rise abruptly from the plains and peaks like Mount Everest and Kinchinjunga are visible from there. The Western or the Punjab Himalayas rise gradually from the plains and the high peaks, being so distant, are hidden from view.

The Himalayas are divided into three parallel zones and their geographical classification is given in the sequel.

(1) **The Great Himalaya** :—This chain comprises the highest portion of the Himalayas with an average elevation of 20,000 feet. It is, therefore, always snow-clad. The highest peaks like Mount Everest (29,002 feet) Godwin Austen (K2), Kinchinjunga, etc. are all situated on it.

(2) **The Lesser Himalaya** :—The Lesser Himalaya or the middle ranges, which occur below the Great Himalayas comprise the ranges, whose elevation does not exceed 15,000 feet above sea level.

(3) **The Outer Himalaya** :—This range of hills, lying between the Lesser Himalaya and the plains, is also called the Siwalik hills which form low foot-hills of the Himalayas, 3,000 to 4,000 feet in elevation above sea level.

It is thus remarkable that the Himalayas possess a very great variety of climate, vegetation and natural products and are inhabited by very interesting and varied hill-tribes, each possessing its own customs, manners, etc.

Trans-Himalaya :—A fourth zone, *viz.*, the Trans-Himalaya is recognised by some geographers. It was discovered by Sven Hedin in 1906 and in its central part is 140 miles in width which dwindles to about 20 miles at the eastern and western extremities. Its length is

600 miles. Sven Hedin stated that the mountain ranges are ill-defined and confusing. To the immediate north of the Trans-Himalaya, is situated the snow-clad Aling Kangri range. The Trans-Himalaya form the watershed of the rivers draining the Bay of Bengal and those flowing to the north into the enclosed drainage depression. The Trans-Himalaya is crossed by a number of high passes, their average altitude being 17,500 feet, although one (Ding La) is higher than 19,000 feet above sea level.

Karakoram Range :—The exact alignment of the Karakoram is still unsettled but Sven Hedin defined it as the "backbone of High Asia" or the Tibetan region. The width of the southern half of the Karakoram fold is 50 miles up to the Shyok valley, which is 12,000 feet above sea level. A similar width would be reasonable to assume for the northern half. The principal ridges, which descend from the Karakoram crest towards the south are Haramosh, the Masherbum and the Sasir. The first or Haramosh ridge forms a connecting link with the Ladakh range, while the Sasir connects it with the Kailas range. The ridge of Masherbrum, which is separated from the main Karakoram range by the trough of the Baltoro glacier, is crowned by the high peaks of Masherbrum and runs parallel to the main range. This ridge is a secondary crest of this big range. The principal ridges on the northern range comprise the Aghil ridge and the Karakoram watershed. It is noteworthy that the Karakoram, like the Nepal Himalayas, carries some of the highest peaks, *e.g.*, K2 (26,470 feet), and Masherbrum (25,660 feet). The Aling Kangri range, which is a snow-clad mountain, runs to the south of the Karakoram.

Zanskar Range :—This range, which is spelt differently, is a northerly branch of the Himalayas and lies

between the Ladakh Range in the north and the Great Himalaya on the south. It is traversed by the Dras and the Zanskar rivers. Kamet, which is 25,477 feet above sea level, is its most well-known summit. The range is traversed by several passes, Dharma (18,000 feet), Kingri Bingri (18,300 feet) and Shalshal (16,200 feet) and Niti (16,500 feet) being some of the most well-known.

Watershed and Highest Peaks of the Himalayas :— It may be noted that the highest peaks occur on the southern side of the watershed between India and Tibet and are about 100 miles from the plains. The average altitude of the watershed is more than 18,000 feet above sea level, while the passes between India and Tibet are about 16,000 feet above the sea.

High Peaks of the Himalaya

The high peaks of the Himalaya are very important landmarks and the knowledge of these conspicuous prominences can be useful in many a way to the geographer, the surveyer and the explorer. The courses of rivers, and the position of the lesser important landmarks can be easily located with reference to them. Sir Sydney Burrard classified the peaks of the Himalaya into five categories in order of their altitude.

I. The following comprise peaks of the first magnitude which exceed 28,000 feet in altitude above sea level :—

Mount Everest (Nepal Himalaya)	.. 29,002 feet.
K^2 (Karakoram)	.. 28,250 feet.
Kinchinjunga (Nepal Himalaya)	.. 28,146 feet.

Mount Everest :—This is the highest peak of the Himalayas, 29,002 feet above sea level, and represents the highest point on the surface of the earth. It lies in

the Nepal Himalayas. The name was assigned to this peak by Sir Andrew Waugh in 1856 after Sir George Everest, his predecessor as Surveyor General of India. There has been some discussion about the identity of this peak with Gauri Shankar, but this has been finally disposed of by the work of Capt. Wood. In Tibet this peak is called Chongo Lungma, meaning the mother goddess.

Within recent years there have been several expeditions to scale this mountain, and, in their final attempt, Mallory and Irvine, two British mountaineers, lost their lives. It still remains an enigma whether they reached the top or not. Camps to a height of 27,000 feet had been established. The path to the top is really difficult, as there are ice-walls on the way, where once by the snapping of the rope several coolies were hurled down the wall. Respiration at these high altitudes also becomes difficult, and climbing with the oxygen apparatus has also been tried. Leaders of the various expeditions have commented very highly on the performance of Sherpa porters. It may be noted that from May 1 to the early part of June is the most suitable time for climbing the mountain, as with the advent of the south-west monsoons it becomes unsafe, the snow begins to thaw and avalanches fall with terrific fury.

K^2 or Mount Godwin Austen:—It is the highest peak of the Karakoram mountain, which separates Kashmir from Chinese Turkestan, being 28,250 feet above sea level, but represents the second highest point in the world after Mount Everest. It may be noted, however, that there is a tussle between K^2 and Kinchinjunga about the second position. This mountain was ascended by the Duke of Abruzzi in June, 1909, and it represents the highest altitude ever climbed by a human being.

Kinchinjunga :—This is the third highest peak of the Himalayas and is 28,146 feet above sea level. It lies on the Sikkim-Nepal boundary in the Eastern Himalayas, and the beautiful snow-clad peak can be observed from Darjeeling. The view of this stupendous mountain, rising from the region of tropical vegetation to the eternal snows, is claimed to be one of the finest and grandest in the whole world. The mountain lies considerably to the south of the line of watershed between the plateau of Tibet and India, with the result that even the drainage of its northern slopes finds a way to the plains of India.

The peaks of the second magnitude comprise those whose altitude is between 27,000 and 28,000 feet above sea level.

E[1] (Nepal Himalaya)	.. 27,890 feet.
Kinchinjunga II (Nepal Himalaya)	.. 27,803 feet.
Makalu (Nepal Himalaya)	.. 27,790 feet.

The peaks of the third magnitude, whose altitude is between 26,000 and 27,000 feet, are twelve in number. They are listed below :—

Dhaulagiri (Nepal Himalaya)	.. 26,795 feet.
Cho Oyu (Nepal Himalaya)	.. 26,750 feet.
Kutang I (Nepal Himalaya)	.. 26,658 feet.
Nanga Parbat I (Punjab Himalaya)	.. 26,620 feet.
Annapurna I (Nepal Himalaya)	.. 26,492 feet.
Gasherbrum I (Karakoram)	.. 26,470 feet.
Broad Peak (Karakoram)	.. 26,400 feet.
Gasherbrum II (Karakoram)	.. 26,360 feet.
Gosainthan (Nepal Himalaya)	.. 26,291 feet.
Gasherbrum IV (Karakoram)	.. 26,180 feet.
Gasherbrum III (Karakoram)	.. 26,090 feet.
Annapurna II (Nepal Himalaya)	.. 26,041 feet.

Sir Sydney Burrard listed 31 peaks as those of the fourth magnitude, whose height is between 25,000 and 26,000 feet above sea level but only the names of some of the well-known are mentioned below :—

Masherbrum East (Karakoram)	.. 25,660 feet.
Nanda Devi (Kumaun Himalaya)	.. 25,645 feet.
Masherbrum West (Karakoram)	.. 25,610 feet.
Nanga Parbat II (Punjab Himalaya)	.. 25,572 feet.
Kamet (Zanskar Range)	.. 25,447 feet.
Namcha Barwa (Assam Himalaya)	.. 25,445 feet.

Similarly 36 peaks have been listed whose height is between 24,000 and 25,000 feet above sea level and these comprise peaks of the fifth magnitude. However, there are some peaks below 24,000 feet and the names of the most well-known are given below :—

Gangotri (Kumaun Himalaya)	.. 21,700 feet.
Gauri Shankar (Nepal Himalaya)	.. 23,440 feet.
Kailas (Kailash)	.. 22,028 feet.
Kedarnath (Kumaun Himalaya)	.. 22,770 feet.
Trisul East (Kumaun Himalaya)	.. 22,320 feet.
Trisul West (Kumaun Himalaya)	.. 23,360 feet.

Himalayan Valleys :—It has been stated above that the Himalayan chains are separated by longitudinal valleys, sometimes hardly 3,000 feet above sea level. Thus from the valleys at about that altitude, almost with tropical heat, to summits with perpetual snow, exceeding 25,000 feet above sea level, is stretched a complete range of vegetation of the world from the tropics to the polar regions. From these valleys a majestic view of some of the stupendous peaks of the Himalayas, about 25,000 feet or more in elevation and unparalleled in the whole world, is to be observed. Two valleys in this connection, especially deserve mention, *viz.*, (1) the beautiful Vale of

Kashmir and (2) the valley of Khatmandu in Nepal. They are extensive fertile valleys both in length and breadth, and especially in the case of Kashmir it is surmised that it originally represented a lake, the waters of which have desiccated in recent times and the shrunken remnants of which are represented by the Wular and Dal.

Regional Classification of the Himalayas

Sir Sidney Burrard has sub-divided the Great Himalayan range into the following four regions:—

(*i*) The Assam Himalaya from the Tista to the Brahmaputra river.

(*ii*) The Nepal Himalaya from the Tista to the Kali river.

(*iii*) The Kumaun Himalaya from the Kali to the Sutlej.

(*iv*) The Punjab Himalaya from the Sutlej to the Indus.

(*i*) **The Assam Himalaya:—**This portion comprises the region between the peak of Namcha Barwa, 25,445 feet above sea level in the Mishmi country, where the Tsangpo or the Brahmaputra forms a bend to cut across the Himalayas and the Tista river. It is 450 miles in length and includes the Kula Kangri group of peaks 24,784 feet above sea level and the Chomo Lhari, 23,997 feet above sea level. The geological and structural features indicate that the Himalayas extend beyond Namcha Barwa and take a sharp turn to continue southwards into Burma. It is noteworthy that the Assam Himalayas have a very rapid rise from the plains; the foothills are narrow and the Sub-Himalayan region is comparatively lower than in the west.

(*ii*) **The Nepal Himalaya :—**This region extends for a length of about 500 miles and represents the portion between the Tista on the east and the Kali on the west. It includes some of the celebrated peaks like Kinchinjunga* (28,146 feet), Mount Everest (29,002 feet), Makalu (27,790 feet), Annapurna (26,492 feet), Gosainthan (26,291 feet) and Dhaulagiri (26,795 feet) above sea level. It is noteworthy that the Great Himalayan range has a southward curvature and Kinchinjunga marks the southernmost point of the Himalayan curvature as west of that peak the Nepal Himalaya trend to the W.N.W. while to the east of it, the trend of the Assam Himalaya is E.N.E. At the Brahmaputra, the trend almost becomes north-easterly. Near Dhaulagiri, the range bends and bifurcates, and a branch extends towards the north. Near Nampa, there is another bifurcation of the range. It may be noted that in all the other Himalayan bifurcations, the more northerly extension has been considered as the continuation of the great range, but in this case, the southerly branch with the peaks of Nanda Devi and Badrinath has been regarded as the Great Himalaya, while the northerly branch with Kamet and Riwo Pharyul has been called the Zanskar range.

(*iii*) **The Kumaun Himalaya :—**This region has a length of 200 miles and is bounded by the Sutlej on the west. The range bifurcates at Badrinath and at the Sutlej, and the highest peak is Nanda Devi, 25,645 feet in altitude. It includes the well-known districts of Naini Tal, Almora and Garhwal. It is alleged that once this region had about 360 lakes, some of which have completely or partially desiccated. There certainly seems to be some truth in the legend because even today, as described in a subsequent chapter, a number of well-known lakes like the Naini Tal and Bhim Tal occur. Some of the well-known peaks of this

*This peak is spelt variously as Kanchenjunga or Kinchinjunga.

region comprise Nanda Devi, 25,645 feet, Badrinath, 23,190 feet, Kedarnath, 22,770 feet, Trisul, 23,360 feet, Mana, 23,862 feet and Gangotri, 21,700 feet above sea level. The Dhauladhar range constitutes the southerly bifurcation of the Kumaun Himalayas. It is in this region that some of the important and sacred rivers of Northern India like the Bhagirathi, the Jumna, etc. take their source.

(*iv*) **The Punjab Himalaya :—**This portion lies between the Sutlej and the Indus and is about 350 miles in length. Owing to curvature, the Kumaun and the Punjab Himalayas do not follow the same trend. West of the Sutlej the altitude of the range diminishes. East of it there are peaks like Kedarnath, Jaonli and Badrinath, all above 22,000 feet in altitude, but west of it there are few peaks exceeding 20,000 feet above sea level. Where the Sutlej cuts across the Himalaya to follow its course in the plains a southerly branch named the Pir Panjal bifurcates. There are few peaks exceeding 20,000 feet in altitude in this portion and the Zogi La pass is only 11,300 feet above sea level. It is noteworthy that the northern slopes of this range are bare and rugged and enclose plateaux with lakes, while the southern slopes are covered with forests and do not enclose any high plains. The Punjab Himalayas are comparatively much drier and consequently the snow-line is much higher. The Jhelum, after flowing through a very deep gorge, cuts across the Himalayas and follows a somewhat remarkable southerly course through the Potwar plateau. The Himalayas appear to end here in the Indus valley, but recent researches have shown that they continue across the Indus into the ranges of Afghanistan and Baluchistan. The geology or the formations on either side of the bend or the syntaxis, as shown by actual geological mapping by D. N. Wadia, has proved the same.

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The Sind-Baluchistan Ranges :—As noted already the Punjab Himalayas sweep round the Indus and extend towards the south to form the Black Mountains of Hazara, the Kala Chitta and the Margala Hills of the Potwar plateau, the Bugti, the Kirthar and the Mekran ranges of Sind and Baluchistan. It is remarkable that they extend westwards into the mountains of Iran and in fact the whole range, as noted above, forms a part of the great young fold mountain system extending from the Alps, beyond the Himalayas on to the festoons of the islands of Sumatra, Java, etc.

Syntaxes of the Himalayas

Various theories have been advanced about the exact extension of the Himalayas. It is therefore imperative to have a correct idea about the exact extent of the Himalayas. Some consider that the Himalayas terminate near the eastern extremity of Assam and the Indus on the north-west. This is not supported by actual field investigations. The geological and structural features prove that the Himalayas extend definitely beyond the re-entrant on the east in Assam and on the north-west in the N.W.F. Province. In fact there are three sharp and remarkable bends in the Himalayan mountains where they apparently seem to terminate but actually continue on to the other side of the bend. Such places, where the Himalayas bend have been called the syntaxes* of the Himalayas. As noted already the first one is on the east, where the Himalayas take a sharp turn to the south and continue on to the hill-ranges of Burma. The second bend is in the North-West Himalayas. On either side of the axis of the bend, the strike of the mountain, which runs uniformly for about 1,200 miles from Assam to Kashmir, abruptly reverses from a north-westerly to a south-westerly course within an extent of

*Syntaxis denotes a grouping of fold-axes around a point or angle. It implies the re-entrant or bend of a mountain chain.

18 minutes of longitude. The work of D.N. Wadia has shown that the old belief that the syntaxis was caused by the meeting of the two distinct mountain systems, *viz.*, the Himalaya and the Hindu Kush was absolutely incorrect. Many geographers and geologists since Suess had advocated that these mountains had originated through two distinct systems of disturbance, but this is wrong because there is a basic unity of formation, structure and the nature of the rocks of the Himalayan chain from Kashmir to the mountains of Hazara. According to the same author, "each of the folds in the syntaxial system can be traced as a morphological unit from the Hazara side of the re-entrant to the Kashmir side". It has been stressed by D. N. Wadia that the mountain systems of Hazara proper belong to the Himalaya, and are in reality a westerly extension of the Himalayan geosynclinal belt, as seen in Kashmir and farther east in the Central Himalaya. Several theories have been advanced to explain the geniculate bend in the Himalayas and one of them is that the Himalayas have bent round the protrusions or the tongues of the Peninsular foreland. In the case of inflexion in Assam, there are some old crystalline rocks which must have constituted a promontory in the geosyncline of the Himalayas and around which the mountains have formed a bend. It is probable that in the case of the north-west bend there was perhaps a similar protrusion of the Aravallis round which the Himalayas have formed a re-entrant. The third bend is round Quetta where the hill ranges of this region again show a remarkable bend.

But it may also be noted that Sir Sydney Burrard and Dr. A. M. Heron have argued that the primary consideration in the nomenclature of the course of mountain ranges is orography and that orographical considerations prevail over geological and structural. Consequently, the Great

Himalaya should be taken to terminate "where a general drop in altitude takes place and this would appear to be conveniently taken to be at the Indus valley". But it would be useful to know at least the geological and structural continuity of this big and mighty range.

Snow-line :—The snow-line is a summer isotherm of 32°F. and marks the lowest limit of perpetual snow. Its height depends upon (i) temperature and (ii) amount of precipitation, *i.e.*, the greater the snowfall, the lower the line. The study of the snow-line is important because it is the snow which replenishes glaciers, and the economic importance of glaciers has been discussed elsewhere. The height of the snow-line in different parts of the Himalayas facing south is given below :—

The Nepal Himalaya	..	14,700 feet.
The Kumaun ,,	..	17,500 feet.
The Punjab ,,	..	17,000 feet.

Influence of the Himalayas

It is certainly true that if these mountains had not existed, the Indo-Gangetic plains, which constitute some of the richest tracts of India, would have been a desert. It is the Himalayas which intercept the moisture-laden winds coming from the sea and bring about the precipitation of moisture in the form of rain and snow. The latter gives rise to gigantic glaciers which constitute the source of some of the important rivers of Northern India and make them perennial. For the same reason the snow-line on the southern slopes is much lower than on the northern slopes of the same mountains. Very little snow will be found in the summer even at an altitude of 20,000 feet on the northern slopes as the air is so dry that no snow can be precipitated, while on the southern slopes the altitude of snow-line varies from 14,700 feet in the Eastern Himalayas

to about 17,000 feet in the Western Himalayas. But for these mountains, the economic geography of Northern India would have been entirely different. In fact, it would not at all be inapt to remark that just as Egypt is styled the gift of the Nile, the Indo-Gangetic plains may be called the gift of the Himalaya and its rivers.

Excepting on the north-west, the Himalayas form practically an impassable barrier between India and the rest of Asia. With the exception of the north-west, the Himalayas have afforded protection to India along its lengthy frontier of about 2,000 miles. Without the Himalayas, the bitterly cold winds blowing from the plateau of Tibet and Central Asia in winter, which happens to be one of the coldest regions of the earth at this time of the year, would have swept over the plains of Northern India. Had it not been for the Himalayas, India would have experienced an extremely cold climate in winter.

CHAPTER III

PLATEAUX

India possesses many notable plateaux. As stated in the foregoing chapter, the whole of the Peninsular India forms one plateau of the Deccan which has been carved out subsequently by the agents of weathering. In Western and Central India, as a result of volcanic outbursts, another plateau of basaltic lava has been built. Towards the north in Bihar in the districts of Ranchi, Hazaribagh, etc., the plateau of Chota Nagpur occurs. Towards the extreme north-east is the plateau of Assam, while in the north-west occurs the Potwar plateau. In the valley of Kashmir occur some plateau-like hills, which are locally known as Karewas.

Beyond the Himalaya occurs the plateau of Tibet. Although, strictly speaking, it occurs outside the confines of India, being connected with the Himalaya and occurring beyond the Trans-Himalayan zone, its description is included here.

Plateau of the Deccan

Brief references to this plateau have already been made in Chapters I and II. It comprises the whole of the Peninsular India south of the Vindhya range and its elevation, as already stated, ranges from 1,500 to 2,500 feet, although some of the peaks of the Nilgiri hills attain elevations exceeding 8,000 feet above the sea. In the west the plateau is bounded by the Western Ghats which with a narrow coastal fringe rise abruptly above the sea and terminate in an altitude of 2,000 feet near Cape Comorin, which represents the southernmost tip of the peninsula. In the east the table-land is bounded by the Eastern Ghats which run in a series of detached irregular hills in a north-easterly direction. It has already been stated that the plains bordering the Eastern Ghats are much broader than

those on the western coast. The Eastern Ghats have an average altitude of 1,500 feet above sea level and terminate near the Vindhya range which traverses the peninsula from east to west and represents the base of the triangle of the plateau of the Deccan.

This region forms one of the stable land-masses of the world, which have not undergone much disturbance. As noted elsewhere, this region has not been depressed under the sea, except in a few places where marine transgressions have occurred. This region is indeed a part of the old Gondwanaland which was disrupted towards the end of the Mesozoic era, and the intervening regions were submerged under the sea. There are various theories. According to one of them the present plateau of the Deccan is the portion left standing, while the western half has submerged underneath the Arabian Sea. Another theory states that this region received an easterly tilt, when the Gondwanaland broke up. These theories explain the easterly drainage of this region, which has been described in detail in the following chapter.

The rocks composing this plateau are the various Archæan gneisses and other crystalline rocks, and there is a large mineral wealth associated with them. Overlying these rocks is a great thickness of unfossiliferous rocks of the Dharwar age. In passing, it may be mentioned that large deposits of gold, iron, mica, monazite, manganese, magnestite, bauxite and laterite are associated with the older rocks. In some of the river valleys rocks of the Lower Gondwana age and forming some of the large coalfields of India occur. The occurrence of these minerals will be described in Part II of this treatise.

The region being very extensive both in longitude and latitude, its geology, soils, minerals, climate, vegetation, etc., have been discussed in appropriate places.

Deccan Trap Plateau

In Central and Western India, there is an extensive plateau-like elevation which occupies an area of nearly 200,000 square miles, covering large tracts of the Central Provinces, Central India, Bombay, Cutch and Kathiawar. This plateau is composed of basaltic lavas, which are believed to have been poured forth through fissures and have spread out over an extensive region in nearly horizonal sheets. These lavas extend as far as Amarkantak and Sirguja on the east; the well-known plateau of Amarkantak, about 3,500 feet above sea level, has sources of three well-known rivers located on it. To the south they occur as far as Belgaum in the Bombay Presidency and to the south-east as far as Rajahmundry. In the north-west they have been found in Cutch. Rocks of the same age and with the same characters have been found as far as Sind, and it is believed that these outlying

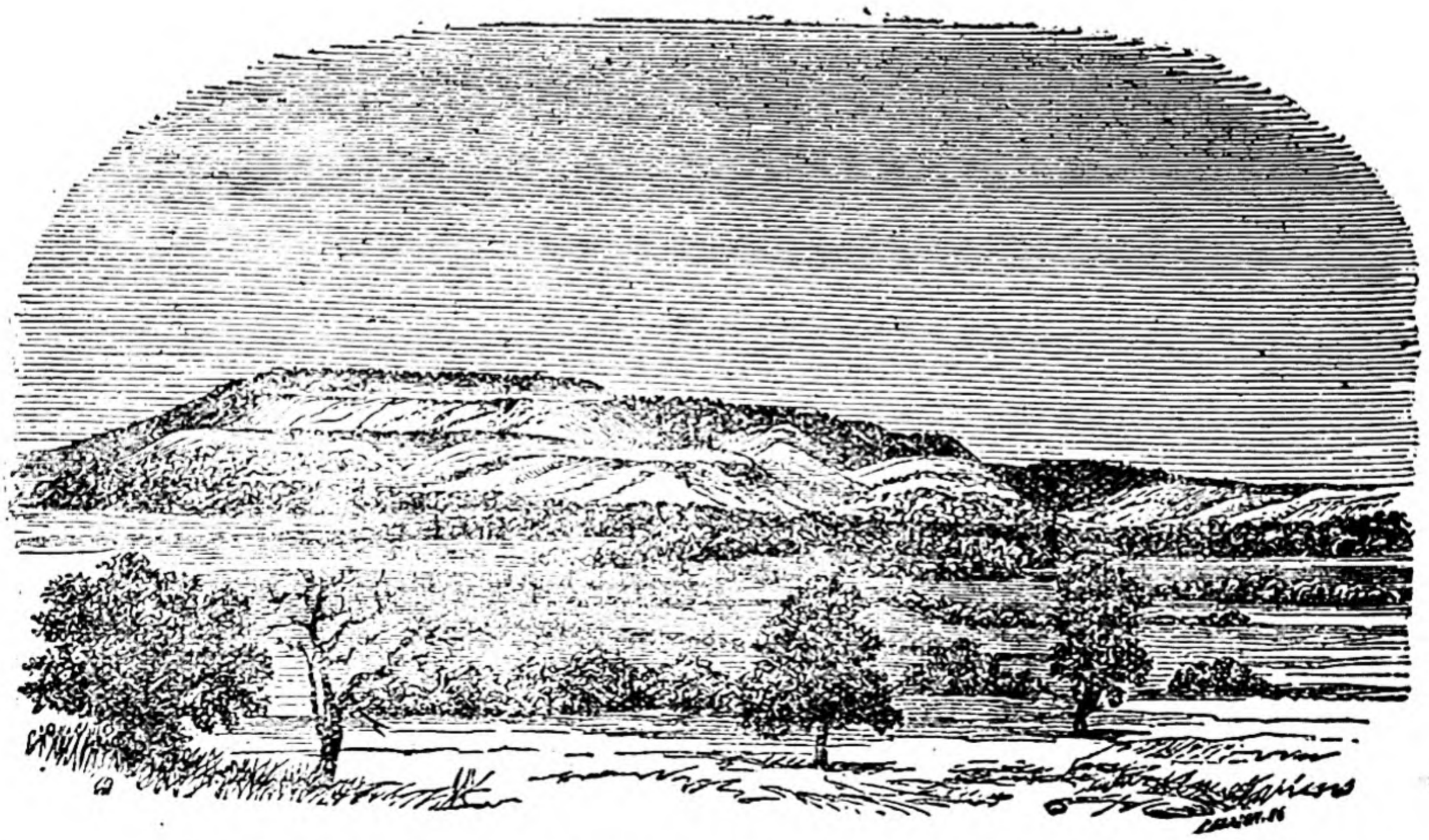

Fig. 3.—Showing the Deccan Trap plateau country (Oldham).

patches were once connected with the main mass but have now been detached as a result of erosion. It has been calculated that originally these lavas occupied half a m illion square miles.

These lava flows form flat-topped hills (see Fig. 3) with terrace-like elevations in places. These lavas were poured forth towards the end of the Mesozoic or the beginning of the Tertiary Era, and in fact the manifestation of this volcanic activity on such a stupendous scale may have coincided with the upheaval of the Himalaya and the breaking up of the Gondwanaland. These highly fluid lavas were erupted intermittently until a basaltic plateau, in places several thousand feet in thickness, had arisen. In places these lava flows are separated by ash and tuff beds, scoriæ and green earth and even sedimentary strata, which are called inter-trappean beds. The fossils found in these intertrappean beds have helped in fixing the age of the lavas.

The presence of ash and tuff beds suggests that some of the eruptions were of explosive character, but in the main they were quiet upwellings of lava through fissures.

The maximum thickness of the lavas has been estimated to exceed 7,000 feet, but towards the east and the north their thickness decreases very greatly. In Cutch their thickness is about 2,500 feet. At Amarkantak the thickness is about 500 feet. East of the town of Nagpur, it is hardly 50 feet in places, while near Jubbulpore in the Chui and Bara Simla and Chota Simla hills, it is about 20 to 30 feet.

The thickness of the individual flows has been found to vary greatly from a few feet to about 120 feet. At Bhusaval a boring was put down to a depth of 1,217 feet. It passed through 29 flows and the average thickness was found to be 40 feet. In the Chhindwara district the

average thickness of a flow proved to be 70 feet. These basic lavas, having been very fluid, have travelled sometimes as much as 60 miles and even more.

Folding of the Deccan Trap :—Generally, these lava flows, as in the neighbourhood of Jubbulpore and Nagpur, appear horizontal but they show gentle inclination near Bombay. In the Linga area of the Chhindwara district and other places they appear folded. Likewise, in the Satpura region they show slight departure from horizontality, showing that they are believed to have been disturbed subsequent to their eruption. In places they have undergone faulting.

Economic Importance :—These dark-coloured basalts furnish an important road metal and building stone. In this region, near Poona, for example, buildings are constructed of this rock. Often this rock is trimmed into setts, which are used for paving, *e.g.*, the pavement outside Nagpur railway station.

These basalts enclose kernels of chalcedony, carnelian and agates which are cut by lipidaries into ornamental articles, and there was once at Cambay a great market for them. In places some river and beach sands derived from these traps are magnetic and when sufficiently rich in iron they are smelted.

These traps yield a reddish to brownish soil, which assumes a darker appearance in cultivated regions. This soil is known as *regur* or Black Cotton soil which represents one of the most fertile soils of India. This subject will be treated in detail in the chapter on soils.

It is also noteworthy that this rock on weathering yields rich deposits of bauxite and laterite. The former is used as an ore of aluminium and such deposits occur in the Belgaum district of Bombay, etc. while laterite furnishes

a building stone and a road metal of inferior quality. By some of the primitive tribes it is still used as an ore of iron.

Plateau of Chota Nagpur

In Bihar lies the plateau of Chota Nagpur, comprising the districts of Gaya, Hazaribagh and Ranchi. In the stricter sense of the word there are three plateaux, one in the Ranchi district and two in the Hazaribagh district. Sometimes the region is very broken and is composed of several ranges or groups of precipitous hills, which are traversed by deep valleys which may be broad in places. In the district of Ranchi this plateau is observed beyond Ramgarh, where the granite gneiss builds the Chittupallu Ghat after an ascent of about 1,000 feet above the neighbouring ground. The town of Ranchi is situated on this plateau, about 2,000 feet above sea level. The plateau, which is gently undulating, extends for a long distance to Lohardaga and farther south. This town was once the headquarters of the district of the same name and enjoys a large hinterland. All the trade of the neighbouring region passes through it. On the plateau terraced fields are to be observed, where paddy is extensively grown. The annual rainfall ranges from 50 to 60 inches a year ; the average annual rainfall for Lohardaga being 56 inches.

Geology and Minerals:—The plateau is built of metamorphic schists and quartzites into which granite-gneiss has intruded. The dome-shaped hills of this granite-gneiss standing above the general level of the plateau are seen to advantage near Ranchi as at other places as well. Of course in a great part of the area this gneiss is the dominant rock. It yields a medium type of light-coloured soil, which becomes reddish in places. The plateau is very rich in minerals. In fact it has aptly been described as "the storehouse of strategic minerals",

Almost inexhaustible reserves of bauxite along with laterite occur in the various plateaux of the Ranchi district. Likewise, 80 per cent. of the quality mica of India and in fact of the whole world, which is a very important strategic mineral, comes from this area. Chromite, an important refractory, also occurs in the district of Singhbhum. Kaolin, white and yellow in colour, is also found in the Chota Nagpur Raj. Quartz and felspar, which are used in the ceramic industry, are also found in large quantities. Coal, gold and copper also occur. An inexhaustible supply of building stones and road metal occur in this region.

A Series of Plateaux :—Ghats in the Deccan Trap are well-known; but the author has observed a series of similar ghats or plateaux of the granite-gneiss in the Ranchi district. Beyond Ranchi Road railway station and past the present Cantonment of Ramgarh, as already noted, there is an ascent of the Chitupallu Ghat. On this plateau, which is really the lowest plateau, Urmanjhi, the towns of Ranchi, Lohardaga, etc. are situated. Its elevation is about 2,000 feet above sea level. Almost due west of the southern end of the town of Lohardaga another plateau is observed. Taking the plateau of Lohardaga as the lowest or the first, the second plateau is situated above the Tetarghat and on this plateau the villages of Gamharia, etc. are situated. The elevation of this plateau above the Tetarghat is about 2,950 feet above sea level.

The second plateau is succeeded by the third or the highest plateau. To-day a number of small flat-topped hills are to be seen, which represent detached parts of the original highest plateau. Towards the W.S.W. of Tetarghat occurs Lalmattia Pat, which is slightly over 3,400 feet above sea level. However, there are a number of other plateaux, *e.g.*, Dudha Pat, Dhulua Pat, Garh Pat

(3,483 feet), etc., in this neighbourhood. It is noteworthy that the elevation of these plateaux is about 3,400 feet above sea level. The highest elevation of the Bagru plateau near Lohardaga is 3,468 feet above sea level. Similar plateaux occur in the area to the north. These plateaux are built invariably of the granite-gneiss which is capped by bauxite and laterite towards the top.

The author has examined a number of these plateaux and in them occurs an almost inexhaustible supply of good bauxite, the ore of aluminium. For instance, in the Bagru plateau alone, about half a million tons of bauxite, besides a very large quantity of good laterite, occur. This association of bauxite with a flat-topped or plateau-like character of the hills has an important bearing on the origin of bauxite. It was so far considered that this bauxite occurring on these plateaux has been derived from the Deccan Trap, but it may be noted that the Deccan Trap was observed nowhere in these hills. It is therefore noteworthy that the granite-gneiss in this region of the plateau of Chota Nagpur builds a series of ghats or plateaux, and that bauxite and laterite have been derived by the alteration of the granite-gneiss.

Forests :—The hilly areas, which have not yet been brought under cultivation, are covered with forests which are mainly private and fairly dense in places. These forests are dry deciduous in character and the Sal (*Shorea robusta*) is the most important species. Other important species comprise Pyal (*Bucannia latifolia*), Asan (*Terminalia tomentosa*), Jamun (*Eugenia jambolana*), Sisso (*Dalbergia Sissoo*), Baija (*Pterocarpus marsupium*), Haldu (*Adina cardifolia*), Semal (*Bombax malabaricum*), etc. The bamboo comprises the *Dendrocalamus strictus* variety. Sometimes remnants of the old *Sal* forests are to be seen on the lower plateau, for example, near Senha beyond Lohardaga.

This area is inhabited by unsophisticated tribes who are largely devoted to agriculture. It is in this region, although not far from Lohardaga, that the Asurs still smelt laterite with the help of charcoal for manufacturing iron and steel. The plateau is drained by rivers like the South Koel and other *nalas* but the soil being largely porous, a large portion of it sinks into the ground. There is scarcity of water during the dry season. In places shallow wells have been dug and irrigation for growing vegetables, etc. is practised with the help of water lifts. It will help greatly towards the prosperity of the region if water during the rains is collected in suitable reservoirs by building dams across the narrow portion of the valleys. The author during his several visits to this region has observed an interesting fact: that the plateau being gently undulating, crests and troughs are repeated and if in the troughs or basins wells are dug, particularly where alluvial detritus has accumulated, potable water is met with at shallow depths. In such areas tube-wells could also be sunk which could yield a decent supply of water. Of course in the higher regions of crests water would be found at much greater depths.

Plateau of Assam

The Assam Range, running east-west, separates the valley of the Brahmaputra from that of the Surma. The central region represents a fine plateau which rises abruptly from the Surma valley to an altitude of 4,000 feet, while the height of the Shillong peak is 6,450 feet above sea level. It descends to the Brahmaputra valley in a series of low hills. The area is composed of gneisses, schists and granites and is really a part of Peninsular India which obviously extends here in a north-easterly direction under the alluvium of the Brahmaputra. On the southern flank of the Shillong plateau, Cretaceous and Tertiary rocks are exposed, which

extend on to the adjoining hills on the east and the south. The direction of strike over the greater part of Assam is north-east and south-west but in the western part of the plateau, the strike becomes east-west. In the Mishmi hills, which represent the extreme corner of Assam, the strike becomes north-west—south-east, showing that the Himalayan rocks follow a turn here. The Assam Range is a block of ancient rocks, which has been affected by two thrusts, one directed to the south from the Himalaya and the other north-west-wards from the Patkoi and Naga hills.

The local people are mainly Khasis. The region, in common with the province of Assam, receives excessive rainfall. Cherrapunji, the rainiest spot in the world, is located on this plateau. Coal occurs in this area and large reserves of limestone occur in the southern part of the range.

Potwar Plateau

The Potwar plateau, which geographically occupies parts of the Jhelum, Rawalpindi and Sargodha districts, lies between the Salt Range and the Hazara mountains. It is 150 miles in length and 60 miles in breadth. Strictly speaking, it is a folded synclinal trough and is also known as the Soan syncline and its axis runs in an E.N.E.-W.S.W. direction. Its average elevation is 1,500 feet above sea level. Geologically, it is built of sandstones and clays of the Murree and Siwalik periods. It is probable that the basin also includes the Palæozoic and Mesozoic rocks, but the whole plateau is believed to rest on the westerly continuation of the ancient massif of Rajputana.

The southern border of the Potwar plateau is represented by the Salt Range which runs in an east-west direction which becomes north-westerly at the western end. The range presents a well-developed escarpment to the south, which overlooks the plains of the Jhelum. The

Sakesar peak, 5,010 feet above sea level, represents the highest point of the Salt Range. It is composed mainly of Carboniferous to Pliocene rocks resting on the Cambrian strata.

The Permian to Eocene rocks are composed chiefly of limestone, generally with a high calcium carbonate content. These limestones, which are of great economic value, occur in inexhaustible reserves. In places like Warchha, Khewra, etc. limestone boulders are collected from the *nalas*, etc. and are exported to all parts of the Punjab and even as far as Delhi and are burnt for making lime, cement, etc. The Sakesar plateau, which is mainly composed of limestone, has several saltish lakes, which have been described in Chapter V. The Salt Range is intersected by deep gorges and ravines, *e.g.*, the Khewra gorge, the Makrach gorge, the Jarhanwala and the Jansukh gorges near Warchha, etc.

Karewas

There are some plateau-like elevations in Kashmir to which the name of Karewas is given in Kashmiri. They are composed of sands, clays and loams with associated gravel and boulder beds. The finer desposits have the appearance of glacial *varves*. They occupy a greater part of the valley of Kashmir. There are two kinds of Karewas : first, whose summits are absolutely flat and build the profile of a table-land. Secondly there are Karewas which slope up the mountain. It is the former type with which we are primarily concerned here and which are best seen in the neighbourhood of Pampur, which is only 5 miles from Srinagar. It is a flat table-land, about 150 feet above the level of the Jhelum River and its alluvial plain. The surface of this table-land is dry and almost devoid of vegetation. Towards the south and across the river is the isolated Karewa of Payach which is triangular in form.

Near Islamabad there is another flat-topped Karewa, about 5,800 feet above sea level and about 250 feet above the surrounding country. The sloping Karewas occur to the south-west side of the valley near Shopiyan. There is a large area which slopes to the north-east, but on the outer edges these Karewas also become flat-topped.

Originally, the Karewas were believed to be of lacustrine origin. This might hold good in the case of the upper portion of these deposits, but later work has revealed the presence of gravel and boulder beds which are of fluviatile origin. Undoubted glacial strata are inter-bedded with them and many definite glacial with inter-glacial periods, proving the oscillation of climate, can be recognised.

It is noteworthy that the upheaval of the Pir Panjal is of post-Karewa age and it is proved that this range has undergone an uplift of about 6,000 feet since the deposition of the Karewas. This phase has not only disturbed and tilted the Karewas but has also affected the rocks of the Salt Range and the Potwar plateau.

It is noteworthy that the lower Karewas are well-known for their plant remains which include oak, pine, birch, beech, willow, poplar, rhododendron, etc., indicating a cold temperate climate of the period. There are remains of aquatic plants, *e.g.*, *Trapa*, *Charophyta*, etc. The mammals of the period include *Elephas*, *Equus*, *Bos*, *Rhinoceras*, *Cervus*, *Sus*, *Sivatherium*, etc.

The Karewas have a great economic importance as they contain large reserves of lignite, a low grade fuel. The importance of these deposits will be appreciated by the fact that all other coal resources are conspicuous by their absence in Kashmir. The thickness of these lignitic coal seams varies from 2 feet 6 inches to about 6 to 8 feet. Thirty

or forty million tons of this material have been proved within a small area but the two known areas occur 40 miles apart, and it is not improbable that the actual reserves may be far greater. These deposits occur in the gently-sloping Karewa deposits which occur near Srinagar at an elevation of 6,000 to 7,000 feet above sea level. There may be a considerable future for these lignitic deposits of Kashmir.

These Karewas yield a loamy or loamy clay soil. When irrigation is possible on a Karewa, it forms a fertile region, otherwise, if the crops have to depend upon rain alone, the harvests are not certain.

Plateau of Tibet

The plateau of Tibet lies north of the Himalayas; in fact the Trans-Himalayan zone actually forms the southern edge of the plateau, which in reality comprises more than one table-land, with an average elevation of 16,000 feet above sea level. The flat portions of the plateau are really troughs between the mountain ranges, which have been subsequently filled with detritus deposited from above. The highest peaks are about 23,600 feet above the sea, while the height of the passes ranges from 16,000 to 19,000 feet above sea level. To the north this plateau is bounded by the Kunlun range.

This plateau is a region of inland drainage and on its surface are located some very large lakes, some of which are saline. The lakes of Western Tibet yield borax, salt and soda. In south-western Tibet the Lakes of Mansarovar and Rakas Tal occur. The Trans-Himalaya thus forms a water-shed between the inland drainage of the plateau and the great rivers like the Indus, Sutlej, and the Brahmaputra of Northern India.

This plateau is built of a great thickness of rocks, which exceeds 20,000 feet and comprise slates, sandstones, limestones and conglomerates, all of marine origin. These rocks are largely of the Jurassic and Cretaceous age. In Southern Tibet crystalline rocks, like the banded biotite-gneiss, which also build the main range of the Himalayas, occur.

Owing to its position the plateau is very dry and bleak as most of the moisture of the monsoons is intercepted by the Himalayas. The total precipitation including both snow and rainfall over a great part of the plateau, excepting the south-eastern portion, which has a higher rainfall in summer, is about 8 inches a year. The plateau must have been affected by all important ice ages, when a great part of the region must have been covered by ice-sheets. The vegetation is of Arctic-Alpine character, but the plateau being dry and bleak, does not support much vegetation. A traveller in Tibet once remarked that in places wood, even to make a toothpick, is not available.

The platcau has its specialised type of fauna comprising chiefly yak, musk-deer, Tibetan antelope, wild sheep and wild goats. The yak along with sheep and goats represent the chief beasts of burden. The products of yak's milk provide food to Tibetans. Leopards, bears, wolves, foxes, monkeys also occur. Barley, wheat and peas comprise the chief agricultural products. Wool spinning, knitting and weaving are other important pursuits to provide clothing.

On account of its configuration and its position, the plateau is cut off from the rest of the world and forms a great land of mystery.

CHAPTER IV

RIVERS

In some countries rivers play an important rôle in their economic development. They are a great source of the life and activity of the people. They help in the irrigation of land and their waters can be harnessed to generate hydro-electrical energy. They also furnish cheap water transport and water supply and sometimes determine the location of towns. They represent some of the important inland fisheries and thus supplement the food of man. During floods, new silt, forming some of the fertile soil, is deposited. Generally in the neighbourhood of streams and rivers, some forests are found, which supply some of the timber and fuel requirements of the local people. In view of the above, a study of the rivers of a country is very useful and a concise account of the important river systems of India is given below.

The drainage of India will be treated in the following order :—

(1) The rivers of the Deccan, (2) the rivers of the Extra Peninsular Region.

Drainage of the Deccan

The rivers of Peninsular India may be classified into (*i*) those that flow into the Bay of Bengal and (*ii*) those that discharge their waters into the Arabian Sea. The rivers of the first category comprise the Mahanadi, the Godavari, the Kistna, the Pennar and the Cauvery. The chief characteristics of these rivers are that they have reached their base level of erosion. They have, therefore, only broad shallow valleys and consequently during the rains

the adjoining portion of the valleys are flooded. It will be clear that all these rivers taking their rise from the western mountains flow towards the east. It is considered that the plateau of the Deccan received an easterly tilt at the time of the upheaval of the Himalayas resulting in the easterly drainage of Peninsular India. Another theory is that the present Peninsula represents the eastern half, the watershed being represented by the Western Ghats. The other half is believed to have been submerged under the Arabian sea when Gondwanaland or the Southern Continent broke up about the time of the uplift of the Himalayas. All these rivers have built important deltas at their mouths and there is also a wide belt of the river-borne detritus on the east coast.

The rivers in the hot season almost run dry and are therefore unfit for purposes of navigation on any considerable scale.

Mahanadi River :—The Mahanadi means 'the Great River' and it is an important river of Orissa. It rises in the Central Provinces and traverses Sambalpur and Orissa States in a wide valley, which contracts into a narrow gorge of the Garmul Pass in Daspalla. It is 14 miles in length and barely a quarter of a mile in width and the river flows sinuously around well-forested hills, 1,500 feet to 2,500 feet in height. The river leaves the hills near Cuttack and enters the Bay of Bengal by two estuaries; it reaches the Bay of Bengal at False Point.

At Cuttack an anicut has been built across the river and this water is used for the irrigation canals of Orissa.

The Mahanadi is notorious for its floods. During the rains it is a magnificent river but it shrinks considerably in the dry season.

Godavari River :—The Godavari or the Godi river has its source on a hill in the Nasik district in the Presidency of Bombay. It is a sacred river for the Hindus and at its source the water trickles from a graven image. It flows past the town of Nasik, one of the most sacred places to Hindu pilgrims. Lower down it forms the boundary between the Hyderabad State and the Godavari District of the Madras Presidency. While traversing the Eastern Ghats it flows through a narrow gorge. During the floods the current in the gorge is very strong and the boatmen are nervous of being dashed against the rocks. After debouching from the hills, the river broadens out in the flat fertile ground on which tobacco is grown. Beyond Rajahmundry it bifurcates into the Gautami Godavari and Vasishta Godavari. The river thus enters the Bay of Bengal after flowing for a length of 900 miles. Near the mouth of the first distributary (Gautami Godavari) occur the Sacremento shoals, where in 1867, the U.S.A. steam cruiser *Sacremento* went aground.

Krishna River :—Also known as the Kistna river it takes its rise in the Western Ghats north of the hill station of Mahableswar in the Presidency of Bombay. It traverses the Hyderabad State, where it is joined by the Bhima river in the district of Raichur. It takes a turn to the south-east, when it reaches the Eastern Ghats. After passing Bezwada it enters by two mouths the Bay of Bengal after a career of 800 miles.

Tungabhadra River :—This river, which is an affluent of the Kistna river, is formed by the union of the Tung and the Bhadra rivers. They take their rise in the Western Ghats at Gangamula in Mysore. This river forms frontiers between Mysore and Bombay, Bombay and Madras, and the Nizam's dominions and Madras. It meets the Kistna near Kurnool. On the Tungabhadra, as on some

Plate II

Fig. 1.—Showing the Cauvery Falls.

Fig. 2.—Showing the Cauvery near the Power Generating Station.

of the other rivers of South India, coracles, which are large baskets, are used for the transport of passengers.

Cauvery River :—This river is also known to the Hindus as the Ganges of the south. It rises in Coorg and flows through Mysore. Its upper reaches are sinuous while the bed of the river is rocky. It is flanked by a strip of rich arable land and a number of irrigation dams have been constructed across its course. There are two sacred islands of Seringapatam and Sivasamudram in the Mysore State. The falls of Sivasamudram (Plate II, Fig. 1) are well known. The river divides into two channels which descend about 300 feet in a series of rapids and cascades. The waters of these falls have been harnessed in generating hydro-electric power (Plate II, Fig. 2).

It forms an important delta in the Tanjore district, which owing to its fertility and irrigation is styled "the garden of South India."

The irrigation canals of the Cauvery river and the power generated from its waters have been dealt with in appropriate places.

Narbada and Tapti :—The rivers Narbada and Tapti flow into the Arabian Sea on the west and this is an exceptional behaviour when the flow of the other rivers of the Deccan is taken into consideration. It has been suggested that the Narbada and Tapti have carved out two fissures or fault planes as their channels and the fissures were formed at the time of the Himalayan upheaval. These are estuarine rivers where the force of the currents caused by monsoons and the gales is so powerful that no alluvial deposits can be permanently laid.

Narbada River :—The Narbada takes its rise at Amarkantak and in its upper course it traverses the Central

Provinces, where it flows through a very narrow valley bounded by the Vindhyas on the north and the spurs of the Satpuras to the south. It is a magnificent stream flowing over cascades near the source. Near Bhera Ghat, about 13 miles by road from Jubbulpore, it leaps over the celebrated falls (See Plate III, Fig. 1) and flows through a narrow chasm in the beautiful marble rocks, where the course of the river as actually observed and measured by the author, is hardly 40 feet in width (See Plate III, Fig. 2).

But on leaving the Central Provinces it attains a width of about a mile and flows calmly in the fertile lands of the Broach District of the Bombay Presidency. Past the town of Broach it forms an estuary, 13 miles in breadth. During the rainy season, the river is navigable for a distance of 60 miles in its lower reaches.

Tapti River :—The second river Tapti, which flows parallel to the Narbada, has its source in the Betul district of the Central Provinces and flows across the plateau of Khandesh between the two spurs of the Satpuras. It subsequently enters the plain of Surat and for the last 32 miles of its course it is a tidal river, but it is navigable for only small vessels. The Port of Swally, situated at its mouth and which was famous in Anglo-Portuguese history, consequent upon silting, has now been deserted. Its course has a total length of 450 miles.

In Peninsular India the Western Ghats form the watershed. Only very short and torrential rivers flow to the west and discharge their waters into the Arabian Sea.

Rivers of the Himalayan Region

The drainage of the Himalayas comprises the following important systems described in the sequel :—

(1) *The system of the river Indus.*

Plate III

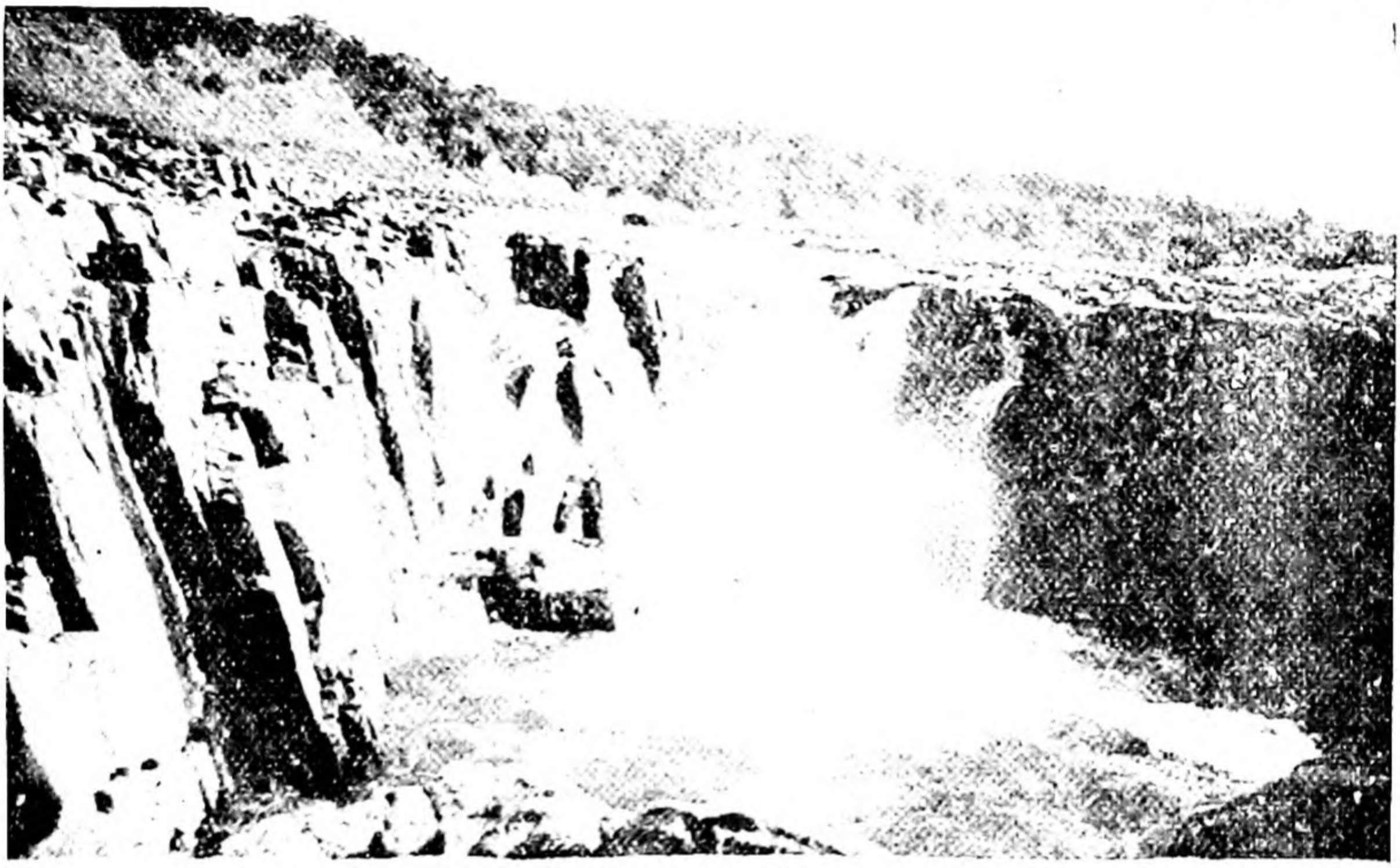

Fig. 1 —Showing the Dhuan Dhar Falls of the Narbada near Bhera Ghat, Jubbúlpore District. —*Photo: H. L. Chhibber.*

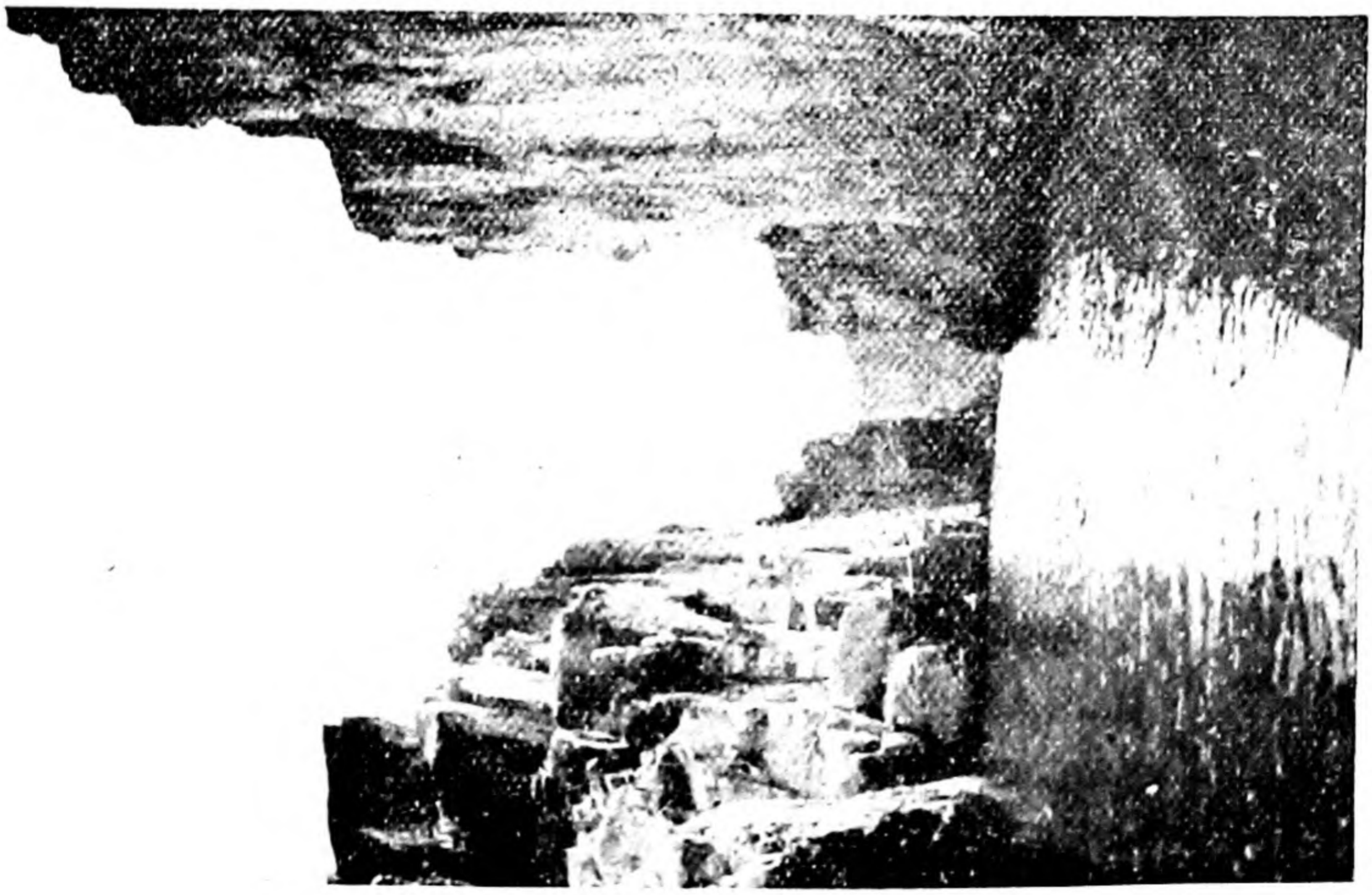

Fig. 2.—Showing the Narbada gorge (Monkey leap) near Bhera Ghat, Jubbulpore District. Here the river was measured to be only 40 feet in width.—*Photo: H. L. Chhibber.*

(2) *The system of the river Ganges.* The systems of the Indus and the Ganges are separated by a low watershed.

(3) *The system of the Brahmaputra.*

The Indus River System

Indus River :—It is one of the three great rivers of Northern India. It takes its rise from the Himalayan glaciers of the Kailas overlooking the Mansarovar lake. It may be observed that the Indus, the Sutlej and the Brahmaputra have their sources close together but the first two rivers flow in a westerly direction while the Brahmaputra flows to the east. The river Indus pursues a north-westerly course for more than 500 miles when the Shyok joins it. The combined waters flow for another 100 miles in a north-westerly direction when the river takes a bend to the south-west. This direction is maintained until the river reaches the Arabian Sea. The Indus is joined by the Gilgit river at the point the river turns to the south-west. It enters into the flat plains of the Punjab, below Darband. At Attock, the valley narrows down to a gorge. At Panjnad, the Indus is joined by the combined waters of the five rivers of the Punjab. The Panjnad has a width twice as much as that of the Indus but the mean depth and the velocity of the latter are much greater. In the province of Sind there is a great fluctuation in the various channels of the river. Evidence is forthcoming that in the prehistoric days a branch flowed into the Rann of Cutch and the gradual shifting of the river to the west has been responsible for the vanishing of many towns which were located on it. There have been other changes also, which are due to the fact that the river brings down large quantities of sediments, which are sufficient to raise its bed above the level of the adjoining ground.

As will be seen in the sequel, the harnessing of the waters of this great river has brought great prosperity to the provinces of the Punjab and Sind. For this purpose various irrigation schemes have been set up. The most important is the barrage in the gorge near Sukkar and combined with other schemes on the Sutlej it is designed to irrigate an area of about 5 million acres in British India together with the States of Bahawalpur and Bikaner. Besides, the Thal project is designed to irrigate about 2 million acres of land in the Punjab.

The Indus receives the combined waters of the five rivers of the Punjab as its main tributary. These affluents have yielded the "best canal system in the world" and a brief account of these rivers has been considered essential. Besides, the waters of some of these have been used in the development of some hydro-electric works in the Punjab.

Sutlej River:—The Sutlej, after the Indus is the largest of the Punjab rivers and takes its source from the Mansarovar lake on the plateau of Tibet, at an elevation of about 15,000 feet above sea level. It follows a course to the north-west for 200 miles and reaches the British border near Shipki and a little lower down it is joined by the Spiti river. From the source to Chini the river has descended 7,500 feet. Flowing for some more distance through the Himalayas it cuts through the Siwaliks at the border of the Hoshiarpur district and bends southwards until Ropar and the head-works of the Sirhind Canal are reached. It then follows a general westerly direction until its junction with the Beas. The Sutlej again turns above the Harika ferry and flows to the south-west until it meets the Chenab at the southern corner of the district of Multan. The river flows for a length of 900 miles and has a large catchment basin. It is believed that the dry bed of the Hakra, which

can be followed in Bahawalpur, Bikaner and Sind, represents the old course of the Sutlej, which carried its waters to the sea.

Beas River:—This river takes its source near the Rotang Pass at an elevation of about 13,000 feet above sea level. It traverses the beautiful Kulu valley and reaches Larji, 3,000 feet above the sea. It then turns to the west and represents the boundary between Kulu and the State of Mandi. It bends again near the town of Mandi to the north-west and follows a westerly direction until it reaches the Siwaliks on the border of the Hoshiarpur district. A little above the Harika ferry it discharges its water into the Sutlej. Its total length is 390 miles, out of which it flows through the plains for about 80 miles.

Ravi River:—The Ravi also rises from near the Rotang Pass in the Kangra Himalayas and it follows a north-westerly course through the southern part of Chamba. North of the hill station of Dalhousie it reaches the Kashmir State border and it then turns to the south-west and at Basoli it is 2,000 feet above the sea. Near Madhopur the head-works of the Bari Doab Canal are situated. It then flows past Lahore and traversing through the north of the Multan district, it meets the Chenab river near the border of the Jhang district. Its total length is 450 miles which is equal to that of the Jhelum, which, however, has a much bigger catchment area.

Chenab River:—This river is formed by the union of the two rivers, the Chandra and the Bhaga. Both these have their source in Lahul near the Baralacha pass in the Himalayas. The united rivers flow through Kashmir State. The Chenab cuts through the Pir Panjal range near Kistwar. It becomes navigable near Akhnur and it then enters the plains of the Punjab. A little lower down it receives

the Tawi river from the west. At Wazirabad it is a big river and is joined by the Jhelum at Trimmu in the Jhang district. The two rivers flow under the title of the Chenab and receive the Ravi from the north and the Sutlej from the south. Beyond its confluence with the Sutlej it is known by the name of the Panjnad.

Jhelum River :—This river takes its source from the spring of Verinag which lies to the east of Islamabad in Kashmir. It is navigable just below Islamabad and flows placidly through Srinagar, the summer capital of the Kashmir State, into the Wular Lake and then to Baramula. From this point the character of the river changes suddenly and as far as Kohala on the borders of the Punjab, it flows like a torrent through a deep narrow gorge. It is bounded by the Kajnag mountains on the right bank and the Pir Panjal on the left. From Baramula to Kohala it has descended from 5,000 to 2,000 feet. At Domel it is joined by the Kishenganga from the north. A little above Kohala it takes a turn to the south but the hills finally disappear near the town of Jhelum. The river follows a remarkable meridional or a north-south course for a distance of nearly 100 miles from its acute bend at Domel in the north as far as the town of Jhelum in the south. It is postulated that the river in this abnormal bend follows a concealed fissure or fracture. Below Jhelum the river flows through the plains of the Punjab. It joins the Chenab at Trimmu. It has a total length of 450 miles but it has an unsurpassing beauty in its upper reaches of Kashmir and the tributary valleys of the Lidar, the Lolab, the Sind and the Kagan glen in the Hazara district. Its silt is very fertile, and supports rich crops.

The Gangetic River System

The Ganges :—Next is the system of the river Ganges and its tributaries. It is an important river of India,

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Plate IV

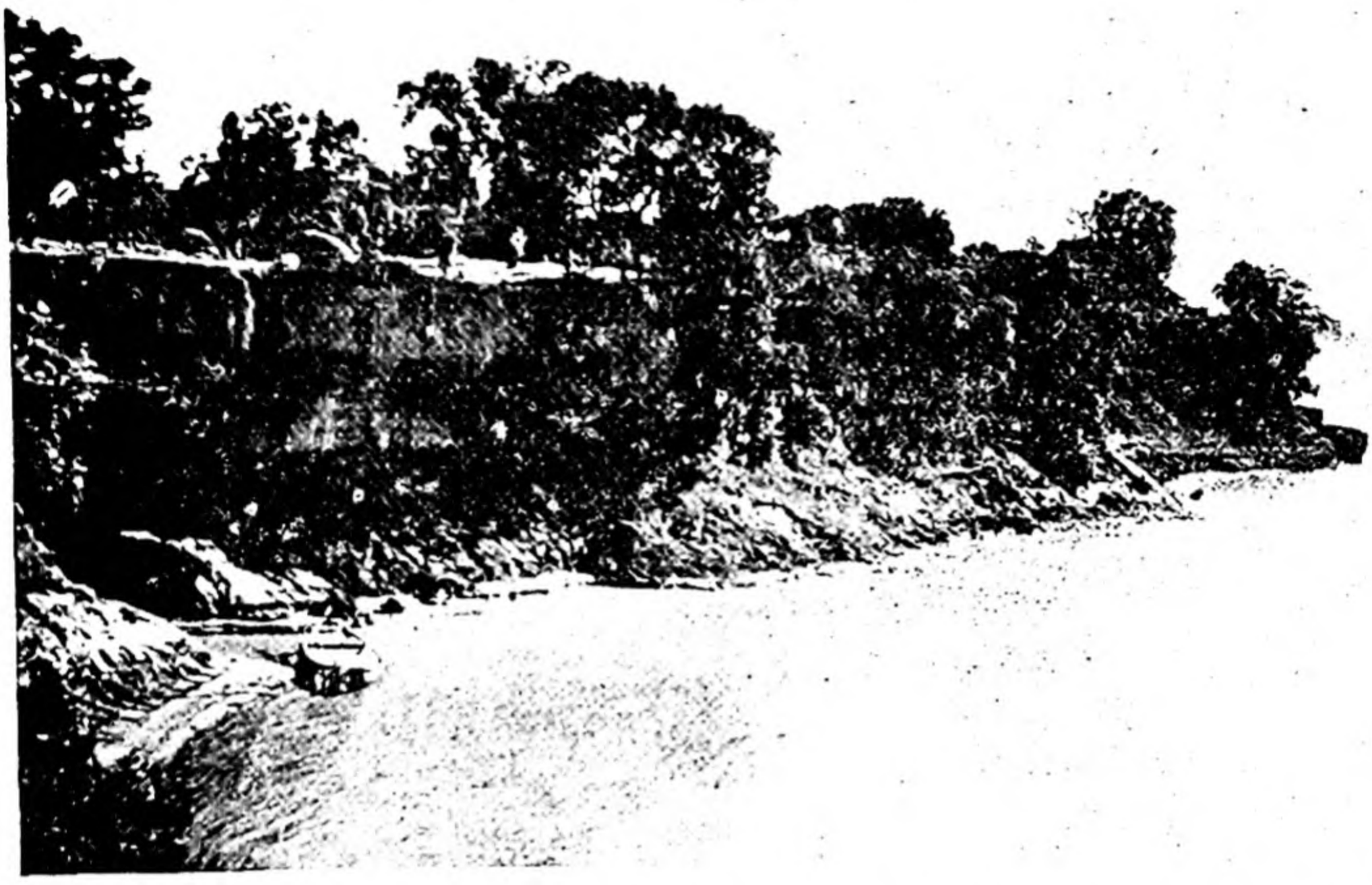

Fig. 1.—The Ganges near Mirzapur. Notice the alluvial cliffs, about 80 feet in height. There is a bay on the right concave bank of the Ganges.
—Photo: H. L. Chhibber.

Fig. 2.—Showing the Jumna near the Bridge just before its confluence with the Ganges. There is a large boat traffic on this river and a large boat is seen unloading its cargo.—*Photo: H. L. Chhibber.*

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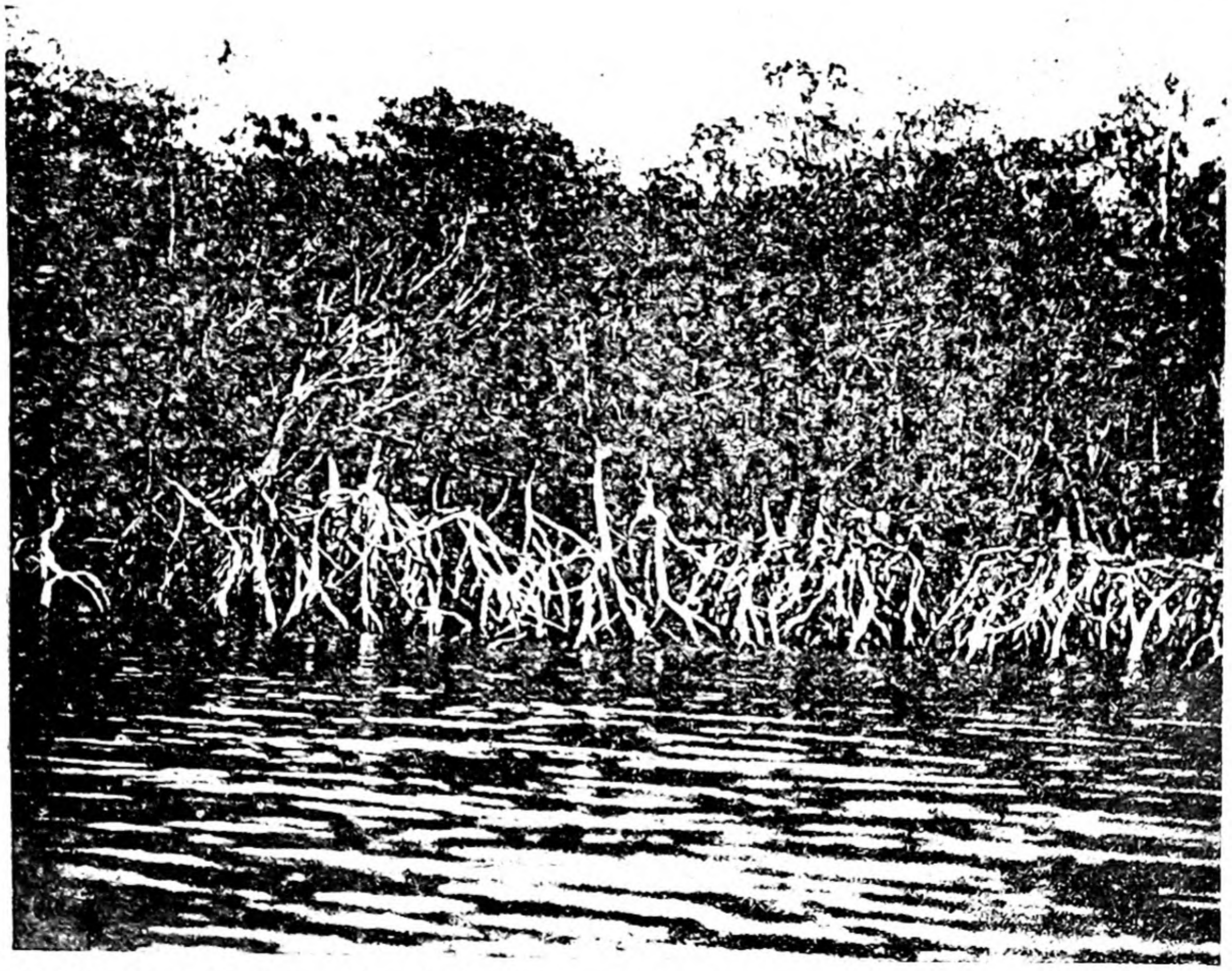
Plate V



Delta of the Ganges—South Sunderbans showing the conditions at high tide near the sea. *(By the courtesy of the Bombay Natural History Society).*

which is highly sacred to the Hindus. It receives the drainage of the southern ranges of the Himalayas. It rises as Bhagirathi from an ice cave of Gangotri, 10,300 feet above sea level. The important tributary, the Alaknanda joins it at Deo Prayag and the combined stream takes the name of the Ganges. It debouches from the mountains at Hardwar and a little lower down the weir of the great Upper Ganges Canal is situated. The river follows a somewhat sinuous course through the various districts of the United Provinces. At Allahabad or Prayag it meets the smaller sister stream, the Jamuna or Jumna. This confluence is considered to be very sacred, where hundreds of thousands of pilgrims bathe every year. The united river flows in an easterly direction still through the U.P. in the districts of Benares, etc., and receives important tributaries, the Gumti and the Gogra. Its course follows through Bihar and just before Patna the Son river meets it from the south.

A little below, the delta commences about 220 miles in a straight line from the Bay of Bengal. The river begins to distribute its water into numerous channels. A little lower down it is joined by the Brahmaputra and the enormous quantity of water flows to the sea by a number of mouths. The easternmost estuary is represented by the Meghna, while the Hoogly is the westernmost and these two streams represent the two sides of the delta. The southern portion of the delta is covered by a jungle with a thick undergrowth and is known by the name of Sunderbans which are the haunts of the Bengal tiger and poisonous snakes (Plates V & VI).

It should be noted that the Hoogly represents the most important commercial channel and the great port of Calcutta is located on it. Above this, the navigation is

carried on by country boats. But it may be noted that before the advent of railway communications, *i.e.*, about the year 1860 steamers plied as far as Allahabad.

Tributaries from South

Jumna River:—The source of the Jumna or Jamuna lies in the Tehri State, about five miles north of Jamnotri hot springs. In its upper reaches it receives the river Tons from the north. Below Kalsi it enters the Doon valley and at Fyzabad in the Saharanpur district it enters the plains. By now the Jumna is a large river and the Eastern and the Western Jumna Canals are taken from this neighbourhood. It then flows throughout the district of Muzaffarnagar and reaches Delhi. A little lower it flows past the sacred town of Muttra. It is joined by the Chambal near Hamirpur and as already noted it discharges its waters into the Ganges at Allahabad.

It may be noted that the Jumna, after entering the plains, has a longer course in the United Provinces than the Ganges but the volume of water is small, especially owing to the making of canals. The traffic is not heavy. In fact in the upper portion it mainly consists of timber, while in the lower course, stone, grain and cotton are transported (See Plate IV Fig. 2).

There are a number of important rivers which take their rise from the highlands of Central India and flow towards the north and join either the Jumna or the Ganges. Thus the Chambal and the Betwa form tributaries of the Jumna while the Son is an important tributary of the Ganges, meeting it from the south. These Peninsular rivers, flowing to the north, are described below.

Chambal River:—It is one of the chief tributaries of the Jumna river and has its sources in the Janapat hills,

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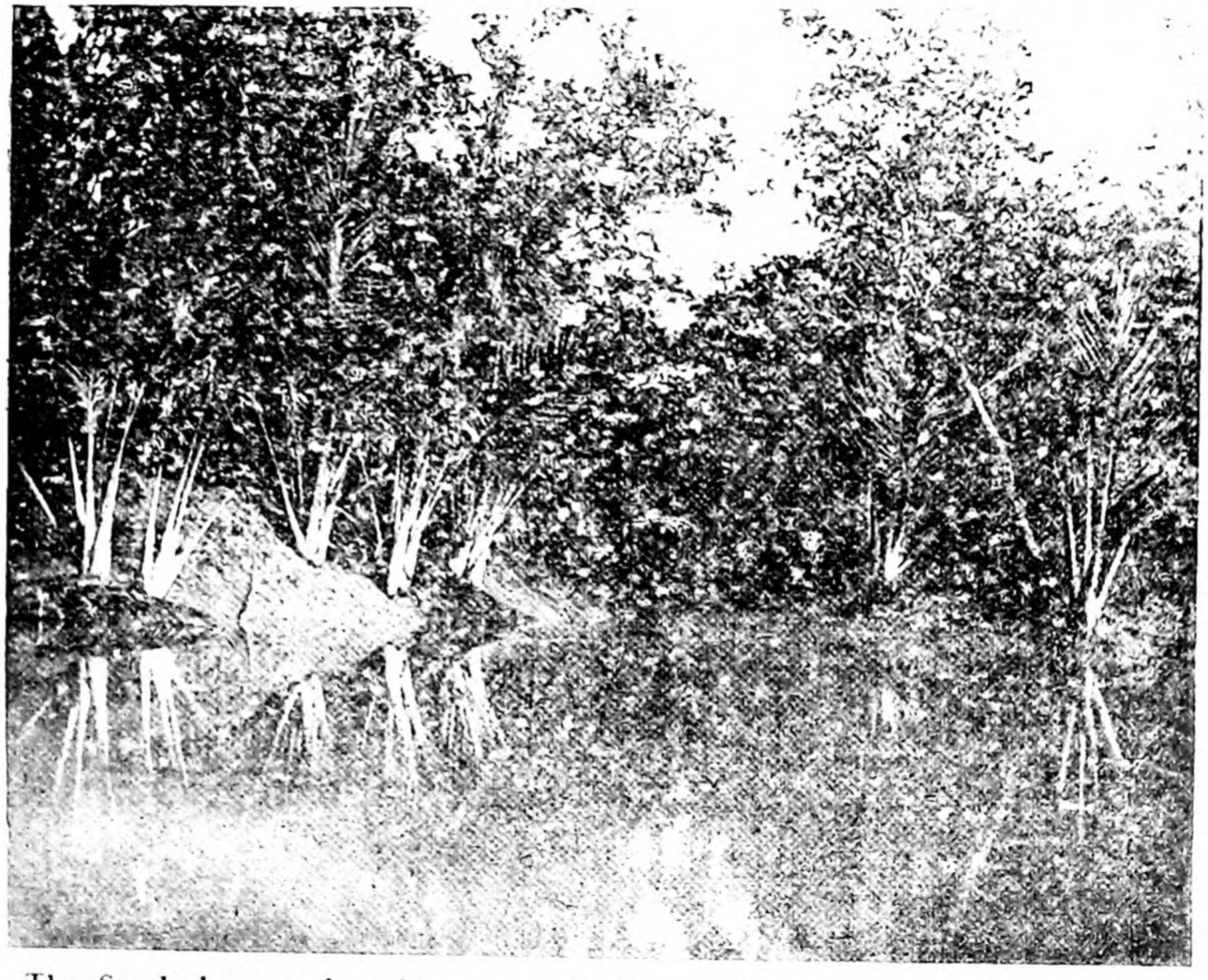
Plate VI



The Sunderbans at low tide. A water channel gives access to the interior of tho Jungle. *(By the courtesy of the Bombay Natural History Society).*

2,019 feet above sea level, in the Indore State in Central India. It follows a northerly course, over the slopes of the Vindhya range and traversing Gwalior, etc., enters Rajputana. Some three miles above Bhainsrorgarh are the famous cascades, the chief having a fall of about 60 feet. Below Kotah and continuing north-east the river is joined by the Kali Sind. Where the boundaries of Jaipur, Kotah and Gwalior meet, it receives the Parbati river. South of Dhaulpur town it enters the open country. Lower down the river forms the boundary between the Gwalior State and the districts of Agra and Etawah in the United Provinces and discharges its water into the Jumna, 25 miles south-west of the town of Etawah. The river is subject to sudden and high floods when it is known to rise about 100 feet above its level in the dry season. The river has an entire length of 650 miles, although the distance in a direct line from its source to the mouth is only 330 miles.

Betwa River :—This river takes its source in the State of Bhopal and flows in a general north-easterly direction for about 50 miles when it enters the Gwalior State. It reaches the Jhansi district in the south-western corner of the Unitcd Provinces and forms its boundary with the Gwalior State. Here it flows over a granite bed for about 16 miles until it debouches into the alluvial plain. It flows into the Jumna near the town of Hamirpur, after a course of about 190 miles in the United Provinces. The river is nowhere navigable but at Parichha, 15 miles from Jhansi the river has been dammed to take off the Betwa Canal. It is a protective work which irrigates land in the Jhansi, Jalaun and Hamirpur districts.

Son River :—This river has its source in the highlands of Amarkantak, near that of the Narbada. It soon falls in a cascade over the edge of the plateau of Amarkantak.

It runs through the Bilaspur district of the Central Provinces and traverses the Rewa State. The river flows through the Mirzapur district of the United Provinces in a deep and broad valley which often narrows down to a gorge. It enters Bihar and follows a north-westerly course and separates the district of Shahabad from those of the Palamau, Gaya and Patna. It discharges its waters into the Ganges about 10 miles above Dinapore. In its lower course the river has a great width, which in places may measure three miles from one bank to the other. It discharges its waters into the Ganges after a career of 487 miles. It may be noted that the river is liable to great and sudden floods during the rains and sometimes causes great disaster in the low-lying plains of Shahabad. It is also noteworthy that the junction of the Son and the Ganges has been gradually shifting westwards and the deserted channels of the Son are to be observed between Bankipore and Dinapore and even as far as Patna.

Tributaries from North

Ramganga River :—This name comprises two rivers, the Ramganga East and the Ramganga West. The former is a tributary of the Sarda, but the latter is the more important river which has its source in the Garhwāl district, some distance to the south of the main range of the Himalayas. Its course for the first 90 miles falls very rapidly and it enters the plains near the Kalagarh fort in the district of Bijnor. It is a large river now and 15 miles below, the Khoh river, which also rises in Garhwal, joins it on its right bank. Their channels are shifting and both these rivers, owing to abundant rainfall in their upper reaches, are liable to floods. The Ramganga having a south-easterly course flows through the district of Moradabad and the State of Rampur. Lower down it traverses the Bareilly, Badaun and the Shahjahanpur districts. Flowing for some

distance into parts of the Farrukhabad and Hardoi districts, it meets the Ganges, after a course of about 370 miles, a little above Kanauj. It receives many tributaries from the Tarai and some larger ones from the Himalaya, the most important being the Kosi in the Moradabad district. Although the waters of the Ramganga are not much used for irrigation, small canals have been taken out from both banks of the Kosi near Ramnagar. It is noteworthy that the Ramganga has a very uncertain and changing course in the plains. In the middle of the nineteenth century it turned its course into the Dojora and flowed past the city of Bareilly but in 1871 it again resumed its former course, about ten miles distant. It is once again beginning to shift towards Bareilly.

Sarda, Kali or Chauka (Chowka) River :—This is really the name of a part of a river system of north-western Oudh of the United Provinces, the headwaters of which take their source in the north-eastern part of Kumaun, close to the frontiers of Tibet. They form the Kali river or Kali Ganga which separates Kumaun from Nepal. After flowing for a little over 100 miles, the Kali is met by the Ramganga East or Sarju at Pacheshwar. Lower down the name Kali is gradually replaced by the Sarda or Sarju. The river debouches in a series of rapids on to the plains at Bramdeo and it now subdivides into several channels which unite again, after a few miles, at Mundia Ghat. Below this point the river forms the frontier between the Pilibhit district of the United Provinces and Nepal. In the former district, the river receives the Chauka on its right bank. This tributary rises in the Tarai but it is also considered a deserted channel of the Sarda. Lower down in Kheri four channels, *viz.*, the Ul, the Sarda or Chauka, the Dahawar and the Suheli are to be observed from south to north. The second channel is called both

the Sarda and the Chauka and after a sinuous course meets the Gogra at Bahramghat. The Sarda Canal, described in its appropriate place, has been taken out of the river Sarda.

Gogra, Karnali or Kauriala River :—This river rising in Tibet flows through Nepal under the name of Karnali or Kauriala. On reaching British territory it forms the boundary between the Kheri and Bahraich districts of the United Provinces. Lower down at Bahramghat, the Chauka, a third branch of the Sarda joins it and from this point the river is definitely called Gogra or Sarju. The river now runs eastward and forms the boundary between the Gonda district on the north and the Bara Banki and Fyzabad districts on the south. Flowing past Ajodhya, the ancient capital of Oudh, it forms the frontier between the Basti and Fyzabad districts. Lower down near Barhaj Bazar in the Gorakhpur district the Rapti and Little Gandak join it from the north. After forming the boundary between the Saran district of Bihar and the Ballia district of the United Provinces, the river joins the Ganges. It is a great river of Oudh and there is a considerable traffic and large quantities of timber, spices and grain are brought from Nepal and are transported to its lower reaches. Ajodhya, the birthplace of Rama, is a great pilgrim resort. Bahramghat and Barhaj (Gorakhpur district) are important trading centres located on its banks. From Barhaj large quantities of molasses and *arhar dal* are transported as far as Bengal and Assam. River steamers, which are both engaged in passenger and goods traffic, ply as far as Ajodhya.

Rapti River :—This river takes its source in the lower ranges of Nepal and first flows southward and then westward. It again turns southward and flows through the

districts of Bahraich, Gonda, Basti and Gorakhpur and after a course of about 400 miles joins the Gogra near Barhaj in the Gorakhpur district. In the districts of Gonda and Basti there is an old bed of the river called the Burhi Rapti which flows some miles north of its present course. The Rapti is navigable for small boats as far as Bhinga in the Bahraich district, while large boats can come up to Gorakhpur which stands on its banks. Many commodities including timber and grain from Nepal, etc. are transported to the Gogra and ultimately reach the Ganges, but with the construction of the railway, the river traffic has fallen considerably.

Gandak River :—This river has its source in Nepal and flowing south-west reaches British territory. It forms the boundary between the United Provinces and Bihar and meets the Ganges opposite the town of Patna. It is a snow-fed stream and its floods are a source of great menace to the adjoining plains which are at lower level than its banks. These plains are, therefore, protected by building embankments along its banks.

There is another stream which is known by the name of the Little Gandak. It also rises in Nepal and enters the district of Gorakhpur, about 8 miles west of Gandak and joins the Gogra in the Saran district of Bihar. The Burhi (old) Gandak has its source in the Nepal hills and runs roughly parallel to and east of the Gandak. It is believed to represent an old channel of the main river and flowing past Muzaffarpur discharges its waters into the Ganges.

The Brahmaputra River System

The Tsangpo or the Brahmaputra :—It is a great river of India with a total length of 1,800 miles. It takes its source from glaciers of the northernmost chain of the Himalayas

not far from the sources of two other important Indian rivers, *viz.*, the Indus and the Sutlej in south-west Tibet. It follows a course of 700 miles through Southern Tibet and runs parallel to the main range of the Himalayas. It receives many tributaries in its upper reaches. On the left bank it is joined by the Raka Tsangpo, west of Shigatse and the Kyi Chu. On the latter stands the sacred city of Lhasa.

It is remarkable that 50 miles south-east of Lhasa, the Tsangpo (as the river is called here) possesses one of the most remarkable inland systems of navigation in the world with a length of 400 miles at a height of 12,000 feet or more. It then turns to the north-east and north and runs through mighty gorges in a series of cascades and rapids and makes a hair-pin bend to turn to the south and south-west and enters the Assam Valley. The mighty river now receives the name of the Brahmaputra. Flowing round the Garo hills it enters the alluvial plains of Bengal and flowing for another 150 miles it joins the Ganges at Goalundo. The united rivers flow under the name of the Padma and reach the Bay of Bengal by the broad estuary of the Meghna.

Undoubtedly, the Brahmaputra in respect of size and utility represents one of the most important rivers. It is 250 miles longer than the Ganges and drains an area of 3,61,000 square miles. The sediments brought down by it from the Himalayas help in the building of land. It is also fertilized by the silt deposited annually during the floods, which helps in the production of rich crops. It also helps in the transport of the produce of the country and imported goods. Undoubtedly it is an important artery of commerce between Assam and Bengal. It is navigable by steamers upto Dibrugarh for a length of 800 miles from the Bay. Its importance in the irrigation and fertilization of the delta is, no doubt, great.

Tista River :—It has its source on the edge of the plateau of Tibet and flows through gorges in Sikkim. It enters north Bengal and flowing through Cooch Behar it joins the Brahmaputra in the Rangpur district. It is remarkable that in the 18th century it followed a southerly course to meet the Ganges but it is alleged that, owing to great floods in 1787, its course was diverted to the south-east and it carved out a new channel to join the Brahmaputra.

Important Recent Changes in Rivers

It is observed that the Thar desert covering Rajputana, part of Sind and the Southern Punjab, is gradually extending and affecting some of the river valleys. The ancient towns of Mahenjo Daro and Harappa must have been located on or near large rivers but now lie buried under the sand as a result of this encroachment. The Rajputana desert is of recent origin and the Rann of Cutch must have extended northwards and it is believed that Rajputana was a wooded and fertile land only as late as 2—3,000 years ago. This extension of the desert must have been aided by deforestation. It is on record that Babar hunted tiger near Agra. Likewise, the districts of Muttra and Aligarh are also becoming gradually arid and desertic.

There is evidence to show that formerly the Sutlej flowed through Rajputana. The Sarswati, the lost river of the Hindu tradition, probably represents the bed of the present Sotar or Ghaggar which flows past near Nahan.

It is believed that the Sutlej flowed separately from the Indus in the early years of the Christian era. Its deserted channel can still be recognised between Sirsa and Umarkot.

The rivers of the Ganges and the Brahmaputra systems have also undergone important changes within historic times. As recently as two centuries ago the Ganges and the

Brahmaputra were independent rivers. The Brahmaputra flowed east of the Madhupur jungle and joined the Meghna river, east of Dacca. The Tista, which was a tributary of the Ganges, now flows into the Brahmaputra.

The ancient Patna or Patliputra was a very flourishing city of the Ganges until the fifth century A.D. It is said to have been located near the confluence of the 5 great rivers, *viz.*, the Ganges, the Son, the Gogra, the Gandak and the Punpun. Some of these rivers like the Son, the Gogra, etc., do not join the Ganges here but their confluences have been shifted by many miles.

Again, the Kosi river in the early part of the eighteenth century flowed below the town of Purnea but it has gradually worked westward across about 50 miles of country, as is now evidenced by its deserted channels.

Some important changes, *e.g.*, the shifting of the river channel of some of the rivers has taken place within human memory. For instance the author observed that the bed of the Gogra near Behramghat has shifted and engulfed almost one-third of the small town of Ganeshpur. Some of the masonry wells, etc, are now seen in the bed of the river at some distance from the bank of the river (see Plate VII, Fig. 1). A river in flood is in great destructive mood and a slight obstacle in its course at that time may shift its course by many miles. Sometimes the old course may be entirely deserted.

Antecedent Drainage:—It may be noted in passing that the drainage of the Himalayas is not a *consequent* one and is not controlled by the relief of the country. In other words, the watershed is not formed by the line of the highest peaks but it lies a considerable distance to the north of them. Such a type of drainage, where the rivers are older

than the mountain ranges through which they flow, is called an *antecedent* type of drainage. In this case the drainage was established before the uplift of the Himalayas and the erosion by the rivers has been faster than the upheaval; in other words, the erosion and the upheaval went *pari passu* and thus the rivers kept their channels open. It is remarkable that the rivers drain the Tibetan slopes as well. They first flow for considerable distances in longitudinal valleys and then suddenly cut across the mountains and reach the plains.

"Cutting Back" of the Rivers:—The Sutlej, the Kosi, the Gandak and the Subansiri, etc. drain a considerable area north of the snowy ranges. These rivers cut through the main snowy range before they find their way through the southern hills to the plains. The antecedent theory, as in the case of the Indus, the Ganges and the Brahmaputra, will not hold in this case because the catchment area to the north of snows is not large enough. Such a behaviour of these rivers is explained by the theory of "cutting back" by which the heads of these rivers are gradually extending to the north. This is due to the fact that there is greater rainfall on the southern than on the northern slopes of the Himalayas. The effect of this process is well demonstrated in the difference in the gradient of the slopes on the Indian and Tibetan sides of the passes.

Transverse Gorges:—The rivers have carved very deep transverse gorges where they are to debouche from the hills and some of the gorges are several thousand feet in depth. These gorges are very narrow and possess almost perpendicular walls.

These rivers have a perennial supply of water, being fed by the melting snow in the hot and dry season. The

waters of these rivers have been harnessed and diverted into canals which irrigate extensive areas and in some cases also produce hydro-electric power. Indeed, the Punjab owes its prosperity to these irrigation canals. The rivers are navigable in their lower courses in the plains and are somewhat utilised as a cheaper means of transport.

CHAPTER V

LAKES

Lakes are hollows or depressions on the surface of the earth filled with water, which may be fresh water, brackish, saline or alkaline, etc. in character. Some of the lakes of Tibet contain borax. Lakes are important as sources of rivers and replenish them with an even supply of water at all seasons, preventing sudden floods or droughts.

The lakes are formed in several different ways and some of the chief modes of their origin in India are given below.

(1) **Alluvial Basins :—**These represent hollows or depressions in the alluvium. They are common in the lower portion of the plains of the Ganges and the Brahmaputra. They are formed by the deserted meanders or the ox-bows of the rivers, *e.g.*, the deltaic lakes of Bengal, etc.

(2) **Aeolian Basins** are hollows filled with water in wind blown deposits, *e.g.*, sand-dunes, etc.

(3) **Barrier lakes** are those which owe their origin to the formation of a barrier which may be formed in several ways :—

(*i*) Tectonic barrier is raised owing to differential earth movements. Thus a river valley may be raised by earth movements and its waters dammed back to form a lake.

(*ii*) A barrier may be raised by landslides and rock-falls, *e.g.*, the Gohna lake was formed by the damming of the Gohna river in Garhwal. But should the lake burst over, it may cause disastrous floods.

(*iii*) By deposition of moraine debris across a glacial stream a barrier lake may also originate. It is considered that some of the lakes of Kumaon and the Pir Panjal were formed in this way.

(4) **Solution Hollows :**—Lakes are also formed by the underground solution of limestone, rock salt, gypsum, etc. Thus a hollow may be formed which may be filled with water.

(5) **Crater Lakes :**—These fill up the craters of volcanoes, *e.g.*, the Lonar lake in Berar.

The Himalayan Lakes

In the Nepal Himalayas there are two lakes, the Khewan Tal and the Dudhkund with an area of 6 and 5 squares miles respectively.

In Tibet there are many lakes, several of which occupy an area of 100 squares miles. A few of them attain a colossal size of 1,600 square miles, or even more. Some of them are an important source of borax.

Kumaun Lakes

There are a number of lakes in the district of Naini Tal in the Kumaun Himalaya. They are located in exceedingly picturesque country and are of all shapes and sizes. There are seven major lakes which comprise Naini Tal, Bhim Tal, Naukuchhiya Tal, Sat Tal, Puna Tal, Malwa Tal, and Khurpa Tal. A brief description of the important lakes is given in the sequel.

Naini Tal Lake :—The hill station of Naini Tal derives its name from the lake. It is situated at the bottom of a valley, which runs in a north-west-south-east direction. The lake is surrounded by high hills on all sides except on its south-east corner which marks the outlet. The Ballia *nadi* takes its sources as a small stream here. The full

Plate VII

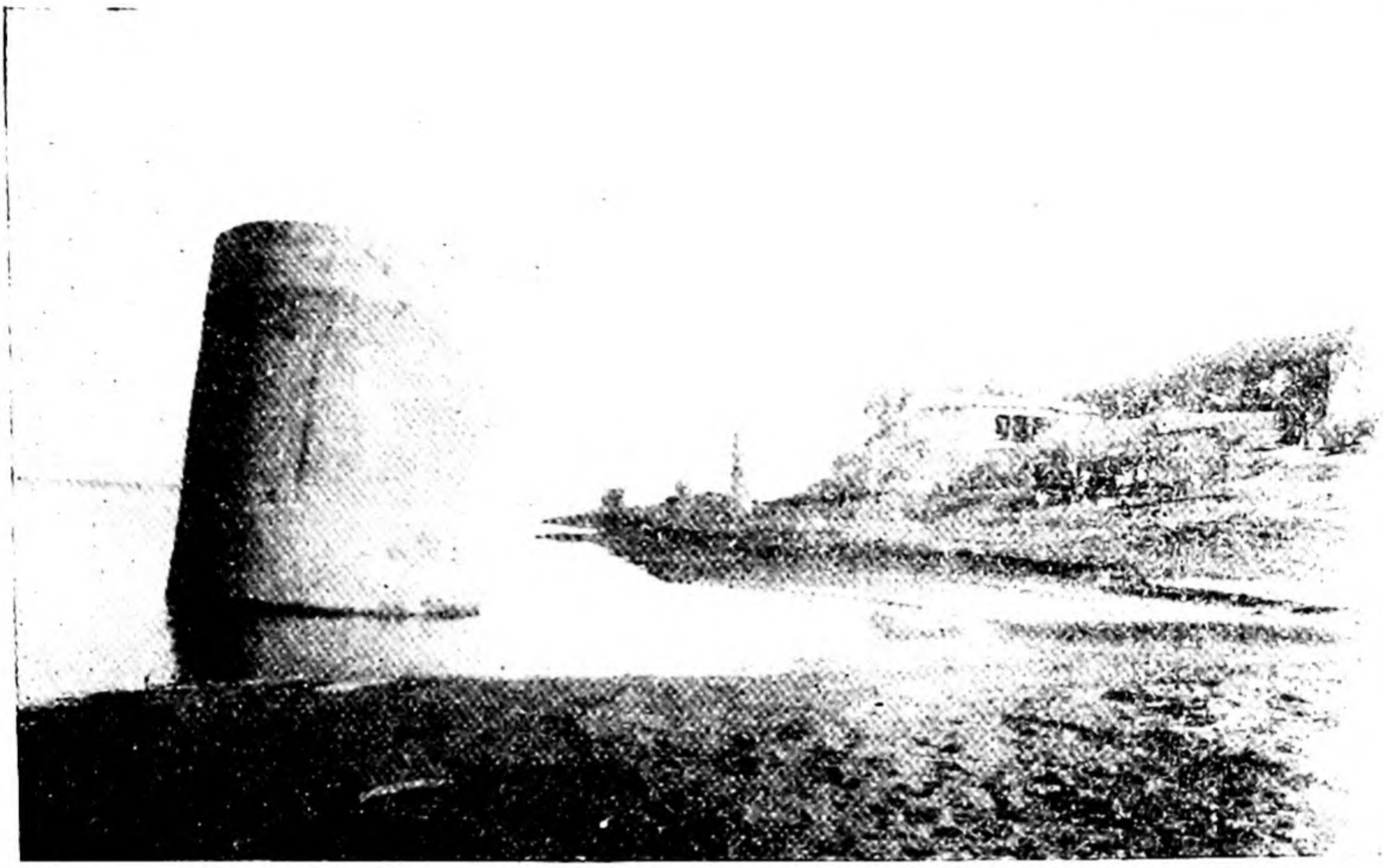


Fig. 1.—Showing erosion by the Gogra near Behram Ghat in the Bara Banki District, United Provinces. Halt of the village of Ganeshpur has been eroded away and one of the masonry wells is seen in the channel.—*Photo: H. L. Chhibber.*

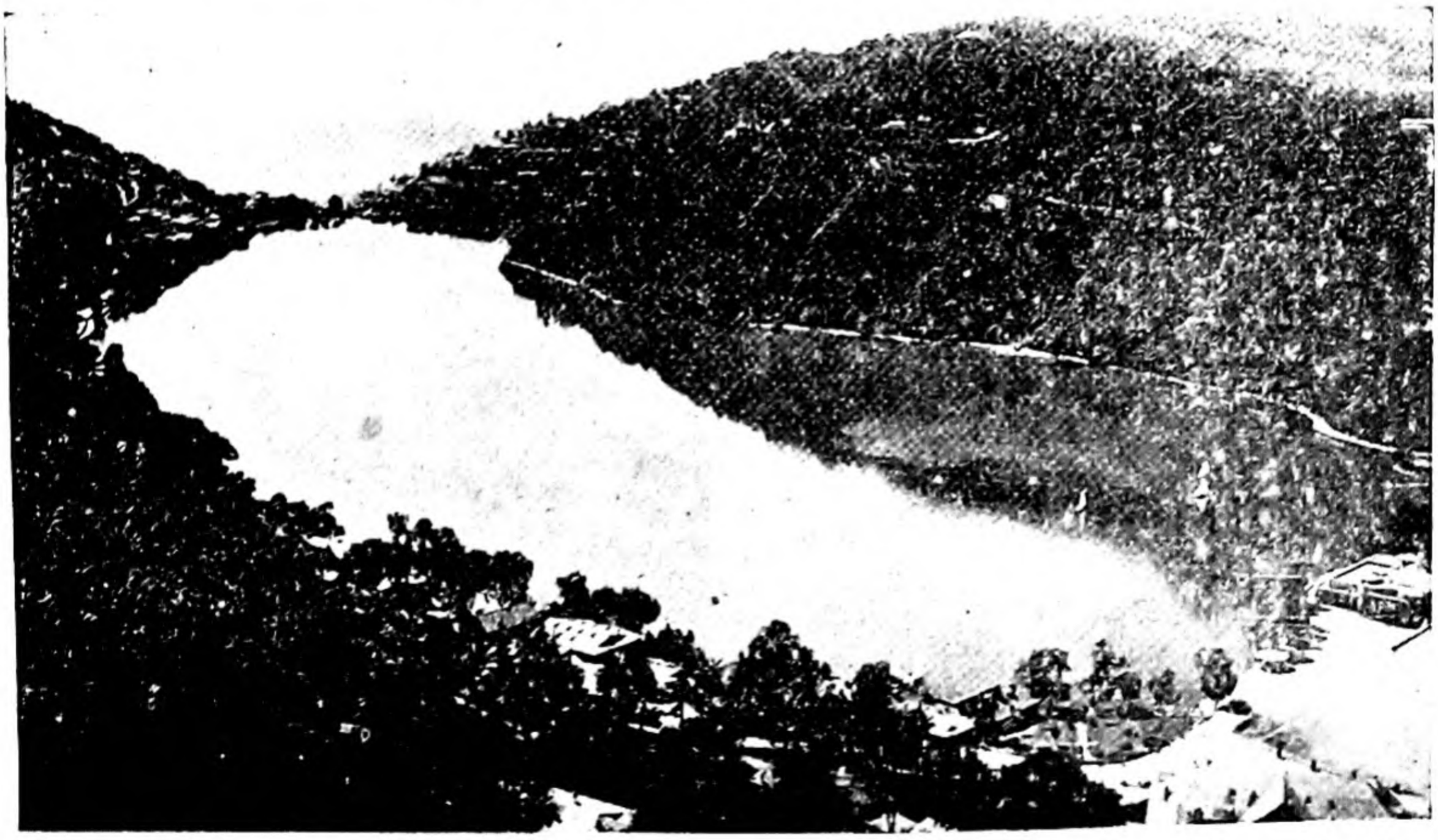


Fig. 2.—A panoramic view of the Naini Tal Lake On the right are the 'flats' which were orginally part of the lake. In the distance is the Malli Tal or the lower end of the lake. On the right of the picture are seen some of the precipitous dolomite cliffs which owe their origin to faulting. On the other side are soft phyllites and plates.—*Photo: H. L. Chhibber.*

supply mark of the lake is 6,356 feet above sea level and thus constitutes the highest lake of this group. Its maximum dimensions are as follows:—

(*a*) Length: 4,703 feet.
(*b*) Breadth: 1,518 feet.
(*c*) Depth: 87.3 feet.

The bottom of the lake is divided into two basins and a ridge, which is only 3½ fathoms underneath the water, separates them.

The hills on the northern and eastern sides are formed almost entirely of purple slates and phyllites with a few small exposures of dolomites and limestones. On the south and the southern half of the western side the lake is flanked by dolomites which form cliffs overlooking the lake, in places. Above the flats at the northern end some scree deposits are to be seen which extend beyond the Sukha Tal (see Plate VII, Fig. 2).

Bhim Tal:—This represents another large lake which is only six miles north of Kathgodam. The shape of the lake is almost triangular. The western side of the triangle is the longest and bends inwards towards the lake. Towards the west the hills are formed mainly of quartzites while on the other side the volcanic traps are the main rock which are seen covering quartzites, which are, in places, exposed in road-cuttings, etc. In the lake there is a small island which is also composed of the volcanic rocks. On the western side of the lake runs a fault as the rocks here are very highly crushed. The height of the Bhim Tal is 4,340 feet above sea level. The length, breadth and depth of the lake, as given by Ball, are 5,580 feet, 1,490 feet, and 87 feet respectively. This lake is the largest of the group. From the north it receives the waters of a small stream called the Nauli *Gadna*. It represents the inlet,

while the outlet is represented by the Bhim Tal *Gadhera* which has carved out a passage in the trap rocks on the east. A weir has been built here to control the outflow of water from the lake, which is used for irrigation in the lower region.

Naukuchhiya Tal:—This lake has a very irregular shape and it is alleged to have nine corners, which give it its name. It is situated two and a half miles to the south-east of the Bhim Tal. Its height is 4,240 feet above the sea level. It is 3,120 feet in length, 2,270 feet in breadth and 132 feet in depth. It therefore represents the deepest lake of the group. Towards the north the lake is bordered by small hillocks. The broad valley extending beyond these is composed entirely of traps. On the other sides the lake is bounded by steep hills composed of massive quartzites.

Sat Tal Group:—As the name implies, this group is composed of seven lakes. Only three lakes are to be observed at present. The largest lake is the Sat Tal proper and one to the north is called the Puna Tal. The Sat Tal is about two miles N.N.W. of the Bhim Tal and has the shape of a horse-shoe. It is 4,219 feet above sea level and is the lowest of the group. The maximum depth is 61½ feet. There is a low ridge running between the two limbs of the Sat Tal.

The study of the origin of these lakes is very interesting. In the past several theories have been advanced to explain their mode of origin. It is almost outside the scope of this work to discuss the mode of origin of these lakes. However, there have been two schools of thought: one considered that they have been scooped out by glacial action, while the other believed that they are the barrier lakes formed by the agency of landslips, etc. The author, who

has also investigated these lakes, considers that no single theory would apply to all the lakes. Each lake had its own mode of origin. Some are only rock basins formed by erosion or solution and the basin was subsequently accentuated by faulting. In the case of the Bhim Tal lake, the author considers that the barrier on the south was created by the eruption of the trap, which in one place was broken through and carved out by the Bhim Tal *Gadhera*. The lakes, apart from their scenic beauty and importance as tourist resorts, also have other economic aspects. They are very rich in many varieties of fish. Mahseer and hill-trout are profusely found in all the lakes.

Kashmir Himalaya

Wular Lake:—In the Punjab Himalayas there are two important lakes situated in the beautiful valley of Kashmir. These are the Wular and the Dal with an area of 44 and 8 square miles respectively and both are situated above 5,000 feet in elevation. The Jhelum flows into the Wular and finds an outlet.

It is noteworthy that the Wular represents the largest lake in Kashmir. Its eastern and south-eastern boundaries are ill-defined but its general length and breadth are 10 and 6 miles respectively. The depth of the lake is variable and in western and north-western parts, where there are no marshes, it is 14 feet. But where the streams enter into the lake, the depth is less and it is continually decreasing as a result of silting. The lake is bounded by mountains in the form of a crescent and they rise from a few hundred to about 5,000 feet above the level of the lake. The northern shore of the lake has an edge of sloping ground which is dotted with villages. Some of this land is flat and seems to have been regained from the lake.

Dal Lake :—This lake lies behind the city of Srinagar on the east. It receives its supply from springs and streams. It has a length of 5 miles from north to south with a breadth of two miles from east to west. At places it is shallow and marshy while at others it is deep with clear water. On three sides it has a mountainous amphitheatre which is 3—4,000 feet above the lake level. On the edge of the lake occur many villages with orchards. There are several famous, beautiful gardens which were constructed by the Moghuls. It may be noted that on the west there are floating gardens, which are made of earth and vegetable matter. These are followed by half-reclaimed marshes and finally comes the city.

The Manas Bal :—This lake occurs about a mile away from the Jhelum river and there is a channel connecting the lake with its right bank. It is two or three miles in length and about a mile in width while the depth is greater than that of the Wular; Drew stated it to be 47 feet and considered that in parts it may be more.

Lakes of Rajputana

In Rajputana there are several salt lakes, of which the Sambhar is typical. These lakes are mere depressions in an arid region and receive inland drainage. The Sambhar is fed by four rivers, *viz.*, the Menda, the Rupnagar, the Kharian and the Khandel and these along with minor streams have a catchment area of some 2,200 square miles. The outlet is effaced by advancing desert sands. The Sambhar Lake during the S. W. monsoon is a shallow sheet of water occupying an area of about 90 square miles. It is mostly evaporated during the dry months and for the greater part of the year its surface is dry. It has been shown that the salt resources of the Sambhar are confined to a saline silt which occupies an area of 80 to 90 square miles and with a depth

of 60 to 70 feet in the centre. It has been calculated that there are more than 55 million tons of salt in the upper 12 feet of this silt. The saline deposit from the bed of the lake is collected and refined. It is advanced by Holland and Christie that the origin of the salt of these lakes is not only due to excessive evaporation but also to wind-borne salt which is blown by the monsoon winds from the Rann of Cutch into Rajputana. It is considered that this wind-borne salt is dissolved by the scanty rains and carried into the lakes. It was calculated by the above authors that the amount of salt added annually is about 1,30,000 tons.

As stated above, there are other smaller temporary lakes in Rajputana, *e.g.*, the Didwana, the Falodi, the Lonkara-Sur and the Kachor Rewassa. It is noteworthy that a brine-impregnated sub-soil is found all over the desert which extends to Sind. North of Rajputana the sub-soil brine is evaporated for salt in the districts south-west of Delhi. It was stated by Holland and Christie that "there may be many Sambhars concealed by the mantle of desert sand."

Lakes of Sind

Manchar Lake:—The province of Sind has a number of tanks or marshes called *dhands*, populous with wild ducks, geese and other water fowl. The largest of these is the well-known Manchar Lake in the district of Larkana. It is hemmed in by hills at its southern end and its water is received from three sources, the Nara, the Aral river and the hill *Nais*. The Nara, the Manchar and the Aral represent merely a loop of the Indus and as such were previously used by all boats as a navigation channel during floods in order to avoid the strong force of the current of the main river.

The lake, during years of good floods, may occupy an area of 200 square miles while in February in a bad year it has an area of about 14 square miles. Its maximum depth in a good year is reported to be 16 feet. The fishing on the lake is said to be marvellous.

Alkaline or Soda Lakes of Sind :—While dealing with the lakes of India, the alkaline or soda lakes of Sind deserve mention as these are important from the economic point of view, the soda industry of Sind having existed from time immemorial. The salt recovered comprises trona (hydrated basic sodium carbonate), with associated sodium sulphate and sodium chloride. Soda, which is recovered by means of evaporation, finds use in many important industries, *e.g.*, it is an important constituent used in the manufacture of glass. These lakes or *dhands*, as they are locally called, occur in the Khairpur State, Nawabshah district and northern half of Thar and Parkar district. The lake water is mainly collected by percolation or seepage from the lower layers of the desert sand which in its passage leaches out the salts present in it. Wherever the water merges out on the impervious clays, it forms marshes or lakes (*dhands*). The *dhands* often form large expanses of water but they seldom have any very great depth. For instance, a lake, one mile in length, may be only 10 feet deep in the middle.

It may be noted that the brackish *dhands* of Khairpur are alkaline. Those of Khipro are saline while those o the Sanghar *taluqa* are intermediate in character. It is noteworthy that the alkaline *dhands* have more prolific vegetation than the saline. The alkaline lakes have a red colour.

These lakes of Sind undergo great seasonal variations in level. Their level is highest during the monsoons and

is lowest during the hottest months of May or June just before the rains. The *dhands* of medium size and with a shallow depth yield the best quality of soda. Those, which dry up entirely yield a very impure deposit.

Khairpur State

Dhands West of the Nara :—The following seven *dhands*, which occur west of the Nara, yield trona locally called *chaniho* : Bulahwari, Bagarwari, Sukchaho, Chughari Chahewari, Tikine, Chilhanwaro and Mithri. Some of the *dhands* yield 100 to 200 tons of *chaniho* in a season. The best producing *dhand* is Mithri whose output of *chaniho* exceeds 200 tons, while Bulahwari, Sukchaho and Bagarwari are good producers with a seasonal production of about 100 tons.

Dhands East of the Nara :—In this group Barko *dhand* is by far the best producer with a seasonal production of about 400 tons. Other *dhands* with a good production are Lambro and Gakanwari; the former has a production of about 300 tons while the latter's output is estimated at 150 tons. Among the moderately productive *dhands* are Lalri Wadi, Matahari, Khabbarwaro and Buxahu, yielding an output of about 100 tons or more. There are other *dhands* with a small production. It may be noted that the output fluctuates, depending upon the rainfall. The *chaniho* is therefore recovered from a different set of *dhands* each year depending upon rainfall.

There are other *dhands* in the Kot Jubo area in the Khairpur State and also in the Nawabshah district and the interested reader is referred to Dr. Cotter's memoir.[1]

Dr. Cotter has mentioned that many of the large *dhands*, *e.g.*, the largest two of Pur Chandar and Khairi contain

1. *Mem. G. S. I.*, Vol. XLVII, Pt. 2, 1923.

each up to 25,000 tons of soda. Besides, there are many alkaline lakes, the waters of which have not been examined.

Khairpur State and the Nawabshah district are the only *chaniho* producing areas and the total production for two years is given below :—

1915-16	..	43,362 maunds.
1916-17	..	25,988 maunds.

Practically the whole production is exported to Karachi and Sukkur, where it finds use in laundering and dyeing clothes and in the manufacture of soap. The *chaniho* of Khairpur State is of superior quality to that of the Nawabshah district. According to the Sind Gazetteer, the purer *chaniho* from the Khairpur State is exported to Bombay and Basra.

Lakes of the Salt Range

The lakes of the Salt Range are interesting. Four permanent lakes exist on the Son plateau. They are situated in an arid region with an average annual rainfall of 15 inches which falls mostly during summer when owing to high temperature the evaporation is very rapid. Their names are given in the sequel :—

1. Son Sakesar lake.
2. Kabaki lake.
3. Jalar lake.
4. Kalar lake.

Son Sakesar Lake :—This is the largest of all and locally it is also called *Samundar* (meaning sea). It lies, as the name indicates, on the Son plateau. It has a length of about three miles with a width of a little over a mile. In normal seasons it occupies an area of 2,000 acres and its catchment area is about 50 squares miles. The lake is situated at an elevation of 2,526 feet above sea level.

The lake is believed to owe its origin to subsidence along a fault plane in the Nummulitic limestone. It is considered that the lake had much greater extension once as testified by the deposits of fine salt to a height of about 250 feet above the present level of the water.

Kabaki Lake :—This lake is usually about a mile in length with a breadth of three quarters of a mile but its extent is greatly increased in years of abnormal rainfall. The lake is situated on the Son plateau about 2,481 feet above sea level.

Kalar Lake :—It lies below the northern slopes of the Salt Range, on the main road from Pind Dadan Khan to Tallagang, almost on the edge of "Potwar". It has a circular outline with a diameter of about a mile. During floods, the lake overflows into the Dharat river which flows close by. The lake has a very flat bottom and is situated at 2,191 feet above sea level. The origin of this lake is believed to be the same as that of the Son Sakesar; in other words, it owes its origin to local movement along a fault.

Salinity of Lakes :—The salinity of the lakes in January, 1909 was determined by La Touche to be as follows. This, however, is likely to increase in the dry, hot season :—

Lake.	*Percentage of Total Salts.*
Son Sakesar ..	1.23
Kabaki ..	0.86
Kalar ..	0.33

The salts of Son Sakesar consist of sulphate of sodium, chloride of sodium, chloride of magnesium and chloride of lime (traces). The chlorides occur in excess of sulphates.

Lonar Lake :—The soda lake of Lonar (lat. 19° 58′ 45″ N., long. 76° 34′E.) is situated in the Buldana district of

Berar. The diameter of the lake at the bottom is about three quarters of a mile while at the top of the cauldron it measures about one and a quarter miles. A spring issues forth on the eastern face of the rocks and replenishes the waters of the tank surrounded by the temples of Shiva. Below the tank there is a cataract, about 50 feet in height of this water, before it reaches the lake.

The depth of the lake is shallow, with a flat bottom. The lake is encircled by a fringe of mud which in turn is surrounded by a coarse grass. Beyond, the walls rise with a slope of 40° to the crest of the lake, about 300 feet high.

The lake is situated in the Deccan Trap region. Some writers have suggested that the hollow is the crater of a volcano or an explosion crater, but it is also considered to have been formed by an abortive volcanic outburst resulting in the formation of a basal wreck or cauldera.

Salts of the Lake :—The salts of the lake consist of a mixture of sodium carbonate and sodium bicarbonate which after conversion into sodium carbonate, could be used in glass industry, etc.

Chilka Lake :—This is the largest lake in the province of Orissa. It is a shallow pear-shaped lake which lies mainly in the district of Puri. It is 44 miles in length and its area varies from 344 to 450 squares miles depending upon the season. The lake represents originally a bay of the sea which has been silted up by the detritus brought down by the rivers and transported up the Bay of Bengal by the very strong monsoon winds. It was ultimately cut off from the sea by a spit created by the same winds. There is, however, a narrow outlet which connects the lake with the sea. This makes it a salt lake from December to June, but during the rains the influx of water brought

in by the rivers is so great that it becomes a fresh water lake. Its average depth is only 5 to 6 feet and its maximum hardly exceeds 12 feet.

Pulicat Lake :—This lake is really a shallow lagoon and extends for about 37 miles along the coast of Madras. It receives its name from the town of Pulicat in the Chingleput district of Madras. The seaward side of the lake is represented by the island of Sriharikota.

CHAPTER VI

GLACIERS

Glaciers have a great economic importance as they constitute the source of some of the important rivers of Northern India. They not only provide the headwaters of such rivers but also continue to feed them by the melting ice when the monsoons have ceased to be active. But for these glaciers the rivers of Northern India would have shared the same fate as those of South India. It is these glaciers and snows of the Himalayas which are in fact supporting the 'best canal system (of the Punjab) in the world' and also the irrigation canals of the United Provinces. Water power has also been generated from the falls occurring in the courses of these rivers. Now water power is even being produced from some of the important falls of canals.

Sometimes by the advance of a glacier a river may be dammed, *e.g.*, the Shyok river. Thus a lake may be created and by the bursting of the dam great disastrous floods may be caused which might cause tremendous havoc in the regions situated below. In such a case a watch has to be kept on the glacial dam in order that the public to be affected, may be given timely warning. Owing to secular, seasonal, and accidental movement this damming of the river valley by an advancing glacier and ultimate bursting of the lake and the occurrence of the floods may be repeated as it has happened in the case of the Shyok river the waters of which have been blocked periodically by the advancing snout of the Chong Kumdan glacier in the Shyok valley. The Central Asian trade route also passes along this valley and as a result of floods bridges are likely to be destroyed, thus causing the breach of communications.

There were two floods of 1879 and 1882 which were caused by the bursting of the Chong Kumdan dam and there was another Shyok flood in 1929 and from these records Mason has calculated the periodicity of the advance of these glaciers and the consequent floods to be approximately 45 years.

The height of the snow-line in the Himalayas has been noted in the foregoing. It would therefore be obvious that the glaciers occur in the zone of the Great Himalaya but not in the Middle Himalaya, whose altitude is below 15,000 feet above sea level. The Great Himalaya, whose altitude exceeds 20,000 feet above sea level, represents great gathering grounds of snow and from these numerous glaciers issue forth; some of the bigger ones are noted and described below.

Glaciers are rivers of ice which accumulates in the valleys in the high altitudes of the Himalayas. These masses of ice move gradually downwards until they reach the warmer latitudes, when their ice melts. The terminus of the glacier is called the snout and at the snout there is an ice cave from which a stream of muddy water issues forth. The height of the ice cave is variable. In places, as in the case of the Pindari glacier, it is only 40 feet, while in the case of the Shankalapa glacier, the ice cave together with the ice cliff above, is 300 feet in height. Thus *Gau Mukh* (cow's mouth) was the name given by the ancient Hindus to the snout of the Gangotri glacier which they considered to be the chief source of the Bhagirathi Ganges. Sometimes several small glaciers unite to form a larger one. The Himalayan glaciers can be classified into (*a*) longitudinal and (*b*) transverse glaciers. The former are the longer of the two and occur in valleys running parallel to the Himalayas while the second type descends more or less perpendicular to the length of the moun-

tains. The longitudinal glaciers have a greater length, greater stability and gentler gradients. Their snouts are at higher altitudes. They are liable to give more reliable data about their secular retreat than the transverse glaciers which are more easily prone to seasonal and other variations.

In the Eastern Himalayas, the glaciers of the Kinchinjunga descend to 13,000 feet, while in Kumaun they come down to 12,000 feet. In Kashmir, it is stated that in special situations they may reach an altitude of 8,000 feet above the sea. On the north side of Mount Everest, the Rongbuk glacier terminates at about 16,500 feet above sea level. This decrease in altitude to which the glaciers descend as one proceeds to north-west is due to two causes. One is that latitude increases towards the north-west. It is 28° in Sikkim, 30° in Kumaun, 32° in Lahaul (Lahul) and 36° in Hunza and the Karakoram ranges. Secondly, there is greater precipitation in the form of rain and not snow as one proceeds to the east, the annual rainfall for Murree is only 55·85 inches, while the rainfall for Darjeeling is 124·38 inches.

Systematic preliminary observations on some of the snouts of the Himalayan glaciers were first undertaken by some of the members of the Geological Survey of India and foreign explorers and glaciers of various regions were studied. These comprised those of north-west Kashmir, Lahaul, certain glaciers in the Kumaun Himalaya, Sikkim, etc.

Deep marks were excavated into the rocks adjoining the snouts of certain glaciers and observations about their recent movements were recorded.

The position of the snout of a glacier is balanced by two factors, *viz.*, the increased temperature of lower altitudes and the supply of ice from above.

Secular changes in temperature or climate result in the secular movements of the snout. These are cyclic in character. These studies in the changes in the snouts of glacier can point to whether the climate is becoming colder or warmer, in other words, how the climate is suited to the habitation by man.

Below is given a list of some of the important and easily accessible glaciers of the various regions of the Himalaya.

Fig. 4—Showing the Baltoro Glacier (Col. Godwin Austen).

Karakoram Glaciers

Kenneth Mason studied 34 glaciers of the Karakoram and the neighbourhood. These like the Hispar, Biafo and the Baltoro represent some of the longest glaciers of the Himalayas. He concluded that the secular movement, if any, is of slow retreat, in other words, the ice of the last ice age is still decreasing. A great number of these glaciers reveal periodic retreat, though there are some notable exceptions. Below are mentioned some of the important

glaciers of this region along with their length, height of the snout and the type represented by them.

Name of Glacier.		Length in miles.	Height.	Type.
Hispar	..	38	10,500	Longitudinal.
Batura	..	36	8,030	,,
Sasaini	..	11	8,000	Transverse.
Momhil Yaz	..	18	9,500	,,
Yazghil	..	18	10,400	,,
Khurdopin	..	26	9,000	,,
Virjerab	..	24	11,320	Longitudinal.
Baltistan-Ladakh				
Biafo	..	37	10,360	Mainly longitudinal.
Punmeh	..	17	11,900	Transverse.
Baltoro	..	36	11,580	Longitudinal.
Siachen	..	45	12,150	,,
Rimo	..	25	16,350	Transverse.

The Siachen glacier represents the second longest glacier outside the Sub-Polar regions. It will be observed from the above that while the longitudinal glaciers attain lengths of 40 miles or even more, while the transverse glaciers do not exceed the maximum length of 26 miles. The maximum elevation of the snout is 16,350 feet while the minimum is about 8,000 feet above sea level.

Glaciers of N. W. Kashmir

In this region, the following glaciers are well-known which have been at least partially studied :—

Name.		Height of Snout.		Type.
Hinarche	..	About	8,000	Transverse.
Barche	..	,,	10,000	Mainly longitudial.
Minapin	..	,,	8,000	Transverse.

Here a brief account of the Machai (Mechoi) glacier may be given as it represents one of the easily accessible glaciers being situated on one of the highways. It is situated near the summit of the Zogi La (11,300 feet) on the Srinagar-Leh road. It is a small transverse glacier and in two miles the fall of ice is 4,000 feet. Lower down the glacier is compressed and terminates in a tongue about 100 yards in width. The ice is almost clear in the centre but is much darker in appearance on the west-side as it is greatly intermixed with the black shale of the overlooking hill. The lateral moraine is well-marked on each side.

In Lahaul in N. W. Himalaya, Sonapani and Bara Shigri glaciers have been studied.

It has been said above that some of the glaciers are the sources of rivers and continue to feed them during the dry season. The Gangotri glacier may be taken as a good example of the above. This glacier is situated in Tehri Garhwal State and is the reputed source of the sacred Bhagirathi Ganges. It is surrounded by peaks exceeding 21,000 feet above sea level. It is noteworthy that the glacier during very recent years has undergone retreat and shrinkage. J. B. Auden has estimated that the decrease in thickness of the glacier is about 200 feet near the snout but is less on the higher slopes.

With regard to the secular retreat it may be noted that the glacier during the Pleistocene period extended as far as Gangotri with a present altitude of about 10,000 feet above sea level. It may also be observed that the glaciers of the adjoining Saraswati-Alaknanda region descended as far as Badrinath which also lies at an elevation of about 10,000 feet above sea level.

Glaciers of Kumaun

The four glaciers, *viz.*, Pindari, Milan, Shankalpa and Poting are the largest and most easily accessible glaciers of the Kumaun Himalaya. Of these the first is of course the best known and is only seven marches from Almora. The average attitude of the snouts of these glaciers is about 12,000 feet above sea level, the exact heights of the snouts for Pindari and Milan being 11,720 feet and 11,340 feet respectively above sea level.

Some Glaciers of Sikkim

These glaciers form the Kinchinjunga group in Sikkim. The Alukthang glacier in clear weather can be seen from Darjeeling and it is about a week's march from this place. The snout, which is usually present at the terminus of most glaciers, is absent in this case. It is further remarkable that this glacier is covered fully with moraine material with the result that no ice is visible save as ice cliff which is formed as a result of shearing. La Touche has remarked that in the absence of the snout this glacier differs from all the glaciers of the N. W. Himalaya with which he was familiar. The deposition of the moraine material adjoining the glacier shows how the glacier has diminished within recent years.

The Guicha glacier represents the second glacier of this region. It forms a single ice-fall and is so badly traversed by cracks that no surface moraine is to be observed.

The Zemu glacier is the largest in Sikkim and represents the only accessible glacier which descends from Kinchinjunga. Its length is about 16 miles. It is remarkable that between the lateral moraine and the hill side trenches occur along either side of the glacier. The origin of these trenches has not been explained satisfactorily.

Size of the Himalayan Glaciers:—A majority of the Himalayan glaciers are two to three miles in length but the extension of the larger ones has been given above. Thus, as noted already, some of the giants of the Karakoram exceed 40 miles in length. The width of some of the largest glaciers varies from one to 2½ miles. In the larger glaciers the thickness of the ice is several hundred feet. In the Fedchenko it is 1,800 feet while in the Baltoro and Zemu it is 400 and 650 feet respectively.

Rate of Movement of Glaciers:—Only a few observations on the rate of movement of the glaciers of the Himalaya are known. General Strachey in his interesting communication* on the Pindari and Kuphini glaciers gave the following theodolite observations showing the rate of movement of the glacier ice:—

	Mean Motion of ice in 24 hours (in inches).	
	At lateral moraine.	On middle of glacier
Lower part of glacier	4.8	9.4
Upper part of glacier	5.3	10.0

These results compared with the rate of motion of Mer-der-Glace (Glaciers of the Alps), which is known to move about 24 inches in 24 hours shows that the rate of motion of the Pindari glaciers is very slow.

The daily velocity of the Fedchenko glacier is 1½ feet while that of the Zemu in Sikkim is only 9 inches. The

*Journ. *Asiatic Soc. Beng.*, Vol. XVI, p. 203.

Italian Expedition of 1909 recorded the daily advance of the Baltoro snout a somewhat higher figure of 5 feet 10 inches.

Former Periods of Glaciation:—In India there have been periods in the earth's history when it experienced much colder climate and the glaciers and ice extended on to much warmer latitudes and lower altitudes than to-day. One such well-known period was during the Upper Carboniferous when a glacial boulder bed was deposited in parts of Peninsular India, Rajputana, the Salt Range, Simla and Hazara regions. In Orissa striated boulders were found in the Talchir boulder bed and it was found resting on a grooved and striated floor of the Vindhyan limestone in the valley of the Godavari. It is noteworthy that similar boulder beds have been found in Australia on the one hand and south Africa on the other, thus proving that a great universal ice age prevailed at that time. In the Salt Range this boulder bed, as observed by the author, is well seen in the Khewra glen near the water reservoir and also near the village of Chideru near Musa Khel in the Mianwali district. Likewise a boulder bed of similar origin occurs near Simla.

The next period was during the Pleistocene and the present glaciers are greatly shrunken remnants compared to those of the Pleistocene period, as polished and striated rock surfaces have been discovered at much lower altitudes.

Pleistocene Glaciation:—Evidence that the present glaciers extended to lower altitudes and higher level has practically been forthcoming from the study of every glacier. According to Italian geologists, who have investigated the moraines of the Karakoram mountains, there is evidence of the great ice-sheet of the Pleistocene glaciation, which may have once been continuous over the whole of Central Asia. In general the Himalayan glaciers are

retreating. A brief account of the erratic blocks of Potwar is given below which occur at an altitude of 2,000 feet above sea level and which, according to some authors, furnish evidence of Pleistocene glaciation in N. W. India.

Erratic Blocks of Potwar:—Large boulders, embedded in the alluvium of Potwar have been described as erratic blocks. Their origin has been a matter of some controversy. Some authors have attributed their peculiar occurrence to catastrophic floods. But this view has been challenged by others who definitely consider them of glacial origin. The advocates of the latter view advance that these blocks were detached with the ice in the form of icebergs which floated on the lakes or lake of that period and were ultimately deposited in their present position. These blocks have been smoothed and striated thus supporting the action of glacial agency. Another view is that by the damming of the streams by transverse glaciers and by the subsequent bursting of the dam, floods may have been caused which transported the erratic blocks to their present sites.

Lower limit of Glaciation:—The lower former limit of glaciation indicating a Pleistocene ice age has been observed in many places. C. S. Middlemiss observed the moraine material in the Hazara district at a height of about 6,000 feet at Gool Maira in the Koonhar valley. East of Garhi Habibullah the moraine, which is undoubtedly of glacial origin, is found at an altitude at least 4,500 feet above the sea.

In North Kashmir, Middlemiss observed that the lowest limit of grassed moraines was just at Gulmarg, 9,000 feet above sea level which represented the lowest limit of melting of ice. But it is also argued that the Karewas are partly of glacial origin. If so, the lower limit of ice

action would become much lower, *i.e.*, about 5,500 feet representing the present altitude of the valley of Kashmir.

In the Pangi valley of Dalhousie region McMahon has recorded testimony of glaciation at 7,500 feet and at Mamul at an elevation of 4,700 feet above sea level. Large boulders of granitoid gneiss considered to be of glacial origin have been observed near Dharmsala at an elevation of only 3,000 feet above the sea.

It would thus not be correct to state that glaciation in the Himalaya has not occurred below 5,000 feet as the mountain has been considerably elevated since the main glaciation of the region. It is therefore apparent that the Himalayan ranges experienced, as evidenced by location of the moraine material at much lower altitudes, U-shaped and hanging valleys, striated and polished rock surfaces, cirques and lakes of glacial origin, the Pleistocene Ice age in common with Europe and America.

Glacial Periods :—It has been found that there was no continuous glaciation during the Pleistocene period but it represented a series of advances and retreats of glaciers. De Terra and Teilhare de Chardin have observed four glacial and three interglacial phases in the valley of Kashmir during Lower Pleistocene to Upper Pleistocene time and the first interglacial period coincided with the deposition of the base of the Karewas.

CHAPTER VII

EARTHQUAKES

India can be divided into three regions so far the occurrence of earthquakes is concerned.

1. **Himalayan Region :—**This region forms part of a very unstable land-mass and the Himalayas have not yet attained their final equilibrium and they are still rising. It has been the scene of some extremely violent earthquakes which have rocked Northern India.

2. **Indo-Gangetic Plains :—**These plains represent the trough or the fore-deep representing the foreland of the Himalayas. They represent the second unit which is affected by earthquakes in a lesser degree than the Himalayas. Sometimes, however, violent earthquakes like the Bihar earthquake of January 15th, 1934 also originate in this region.

3. **Plateau of the Deccan :—**This, as stated in the foregoing, represents a stable land-mass and is practically immune from the occurrence of disastrous earthquakes. The only shock which caused any material damage in this region is that of April, 1843. These three divisions, therefore, represent regions with decreasing intensity of earthquakes from north to south (see Fig. 5).

Fig. 5—Showing Earthquake belts of India (after West).

Below is given a brief account of the important earthquakes which have affected India within historic times since about 893 A.D. The first earthquake of which there is an authenticated record, occurred in 893 A.D. when

an important town on the coast of the Indian Ocean was violently shaken and about 1,50,000 people perished.

The next important earthquake on record occurred on the 6th July, 1505. It effected Afghanistan and Northern India. It is stated that fissures appeared in many parts and extensive landslips caused much damage. There was much loss of life. In 24 hours as many as 33 shocks were felt and the after-shocks continued for a month.

Delhi Earthquake of 1720 :—There was a severe earthquake at Delhi on the 17th July, 1720 at about mid-day. It caused considerable damage to the fortress, Fatehpur mosque and other property. There was loss of life. It is noted that the comparatively severe shocks followed for more than a month with the result that the population of Delhi had to sleep out of doors during that time.

On the **2nd April, 1762** Bengal, Burma and the Arakan coast were affected by a very severe earthquake. It is alleged that the Arakan coast emerged as a result of this earthquake. This is mostly an exaggeration, although a partial elevation of the coastal strip may have occurred. Rocks with oysters were found 40 feet above the ground level. Near Chittagong, 60 square miles of ground were submerged under water.

On the **1st September, 1803** a violent earthquake shook Muttra, Delhi, Calcutta, Garhwal, and Kumaun. At Muttra the domes of several mosques erected by Ghazi Khan were demolished. Several villages were destroyed in Garhwal.

Cutch Earthquake :—On the 16th June, 1819 India experienced one of the most violent earthquakes and its worst effect was in Cutch, where Bhuj the capital was laid in ruins and 2,000 people lost their lives. The towns of

Ahmedabad, Broach, Surat and Poona were all badly affected. In western Cutch, the town of Sindree and the adjoining region sank under water as a result of the tidal waves. A tract of 15 miles was raised which the local people called *Allah Band* or God's Embankment.

Nepal and Bihar Earthquake of 1833 :—North Bihar and Khatmandu were shaken by a severe earthquake on the 26th August, 1833 and 100 houses were destroyed in Khatmandu and similar damage occurred in other places. It may be noted that the recent Bihar and Nepal earthquake of 1934 appears to have occurred nearly a century afterwards.

Deccan Earthquakes :—It is noteworthy that two earthquakes affected the Deccan in March and April, 1843. It has been noted above that the Deccan represents a stable land-mass which is usually not affected by any severe earthquakes. The towns affected included Sholapur, Maktal, Singrurgarh, Bellary, Kurnool, Belgaum and much damage was caused. Bellary represented the epicentre.

Kashmir Earthquake of 1885 :—On the 30th May, 1885 Kashmir was disturbed by an earthquake when about 3,000 people lost their lives. The epicentre was a few miles west of Srinagar.

Bengal Earthquake of 1885 :—There was a severe earthquake on the 14th July, 1885 which was very violent in Bengal but it was also felt in Assam, Chota Nagpur, Bhutan and Sikkim. The affected area comprised 2,30,400 square miles.

Baluchistan Earthquake of 1892 :—This earthquake was experienced over a greater part of Baluchistan and occurred as a result of movement along an old fault which runs along the foot of the Kojak range.. As a result of the

earthquake, about one foot of the land subsided west of the fault.

Assam Earthquake of 1897 :—This was the greatest disaster that Assam had experienced within historic times. Stone buildings were entirely destroyed in Shillong, Goalpara, Gauhati, Nowgong and Sylhet. The earthquake was felt over an area of 1.7 million squares miles. It affected Calcutta seriously.

Kangra Earthquake of 1905 :—The district of Kangra and in fact the whole of the Punjab, was rocked by a very severe earthquake on the 4th April, 1905. More than 20,000 lives perished and the loss was particularly heavy as the earthquake occurred in the early morning when the people were still asleep. Kangra and Dharmsala were completely demolished and the earthquake was felt over an area of 1·6 million square miles. The earthquake is believed to have originated by movements along one of the Himalayan reverse faults.

Dhubri Earthquake of 1930 :—Assam was disturbed by a severe earthquake on the 3rd July, 1930 and the town of Dhubri suffered considerable damage. The total area affected comprised 3,50,000 square miles.

Baluchistan Earthquake of 1931 :—The earthquake, which occurred on the 27th August, 1931, was evidently one of the worst earthquakes that Baluchistan had experienced. About 200 lives were lost. On the 25th August there was another earthquake, the epicentre of which was near Shahrig. It is surmised that both these earthquakes were connected with the sharp bends of the Sulaiman, Bugti and the Kirthar ranges. It is believed that these sharp bends are regions of strain and earth-movements are likely to occur along them.

Bihar Earthquake of 1934:—On the 15th January, 1934, Bihar and a region of Nepal were badly affected by one of the most serious catastrophes. About 10,000 lives were lost and very serious damage was caused at Sitamarhi, Madhubani, Monghyr, Patna, Muzaffarpur, Darjeeling, etc. The valley of Nepal also suffered considerable damage. The earthquake was felt over an area of 1·9 million square miles and it is believed to have occurred due to movement along faults underneath the mantle of alluvium.

Quetta Earthquake of 1935:—On the 31st of May, 1935, Quetta was affected by one of the most severe earthquakes. The town of Quetta was practically destroyed and 25,000 lives were lost and the affected region comprised an area of 100,000 square miles.

It has been concluded that the regional distribution of the severe earthquakes in India is as follows:—

(*i*) North-eastern India including Sikkim, Nepal and Tibet, 31.

(*ii*) North-western India including Baluchistan, Chitral and Kashmir, 21.

(*iii*) Peninsular India, 2.

Causes of Earthquakes:—Although minor shocks originate as a result of volcanic eruptions but more important ones, like the earthquakes noted above, are caused as a result of movements along the weak planes in the earth's crust.

In conclusion, it may be stated that earthquakes are agents of great destruction. As noted in the foregoing, they cause great loss of human lives and property. Sometimes this damage runs into crores of rupees. From the foregoing, the towns and regions, which are likely to be affected by disastrous earthquakes, are known. In

such regions earthquake-proof materials should be used in the construction of buildings and such structures which are more easily damaged by earthquakes must be scrupulously avoided. Thus by foresight and thought damage by earthquakes may be considerably mitigated if not almost entirely eliminated.

CHAPTER VIII

COAST-LINE

The study of the coast-line of India is imperative to a student of geography, geology, engineering, commerce and strategy. A uniform or a broken coast-line may make all the difference in the development of a country. Wherever the coast-line is broken or fringed with an island, like the island of Bombay, harbours for incoming and outgoing ships can be developed and on their site the seaports will spring up which may make all the difference in the commerce and trade of the country and which will of course determine its prosperity.

It may be observed that a very irregular coast-line is suggestive of sinking of a land-mass, while a more or less uniform coast-line with cliffs or raised beaches is attributed to the upheaval of land. India has a coast-line, about 4,500 ~~miles~~ k.m in length but which is comparatively regular with a few indentations. It is for this reason that there is practically no natural harbour on the east coast. It is bounded by broad lowlands, about 100 miles in width. In places, however, this ancient coast-line is broken where large lagoons or lakes may occur. It is familiar that rivers like the Mahanadi, Godavari, Kistna and Cauvery build important deltas at their mouths. These deposits of silt form shallows and shoals which render navigation difficult and hazardous. However, wherever there are no such deposits it may afford a good anchorage, but the east coast is devoid of good natural harbours. Madras has an artificial harbour while that of Vizagapatam has been dredged out of marshes.

The west coast is bounded by the Western Ghats which present a somewhat steep, ghat-like or landing stair weather-

ing. It is broken by valleys which are covered with dense vegetation. The lowland area, bordering the sea is narrow, having a width ranging from 20 to 50 miles. In the north even this width is interrupted as a result of the spurs descending from the Ghats. But in the south in Malabar the hills are farther away, making the plains somewhat more open. Here the Ghats merge into the Nilgiri hills which descend down into the Palghat gap. The lowland area fringing the sea along the whole length of the western coast is very fertile. From Bombay to Malabar the coastline is firm but farther south in Cochin and Travancore it is pierced by inlets and backwaters.

On the west coast there is no large river south of the Tapti. The harbours of Cochin, Marmagao and Bombay on this side are noteworthy. Similarly, there are the Kathiawar ports of which Bhavnagar and Okha are notable. Further north lies the important port of Karachi.

It may be noted that on the coast, fringing the Bay of Bengal, the 100-fathom line runs parallel to the coast at a distance of 50 miles while the 500-fathom line is again about the same distance. But near the deltas like that of the Ganges and other Peninsular rivers these lines naturally extend farther out to the sea. On the west coast, the 100-fathom line runs farther out to the sea. It is noteworthy that the determination of the 100-fathom line or the continental shelf is important because of the existence and development of fisheries in this region. Thus Madras alone has a fishing area of 40,000 square miles.

Important Recent Changes in Coastal Regions

Several important changes have taken place in the coastal area during the Recent and even during historical times. The evidence goes to prove both the submergence and the upheaval of the coast and such testimony is more

noticeable on the eastern coast than on the western coast.

Submergence of Coast:—Definite evidence is forthcoming that the coast has submerged in several places. In the year 1878, a submerged forest, about 20 feet below the mean sea level and with tree trunks standing in their original position, was found during the excavation of the Prince's dock on the eastern side of the Island of Bombay. The trees unearthed in an area of 30 acres numbered 382, of which 223 were found still in an upright position. The trees were found 33 feet below the level of the highest tides, thus indicating subsidence at least to that extent.

In 1910, *i.e.*, 32 years after the above discovery, four trees, three of which were still in an upright position, were found while excavations were proceeding for an extension of Alexandra dock lying to the south of the Prince's dock. The amount of depression indicated by this submergence is about 40 feet. This does not represent the maximum amount of subsidence as similar wood was dredged out at lower levels in the approaches to the Prince's dock. It has to be observed that the forest naturally grew at a higher level than the highest water-mark.

This establishes a gradual sinking of the coastal area of the western side of the harbour of Bombay. It converted the creeks into backwaters or lagoons and flooded the forest area with brackish water.

It is noteworthy that this is not the only instance of the relative change of level of sea and land. The western coast of India forms the edge of the great depression, where formerly the land linking India with Africa, sank under the waters of the Arabian Sea towards the close of the Secondary or the beginning of the Tertiary Era.

Similarly, on the Tinnevelly coast in the Valimukam bay, another submerged forest was observed. The peat beds of Pondicherry furnish evidence of subsidence in the Pleistocene and Recent times.

Upheaval or Emergence of the Coast:—There is definite testimony forthcoming which proves that some of the coastal regions have been raised within the Recent times. For instance, raised beaches containing shells of some of the living species occur about 100 feet above sea level on the Mekran coast of Baluchistan. Coming to the south the Rann of Cutch was a shallow arm of the sea even during historical times. It has now been silted up and represents an extensive salt marsh during the dry season, while during the monsoons it is a tidal flat covered with a few feet of sea water.

On the Kathiawar coast occurs a marine limestone called Miliolite which is composed chiefly of the remains of the foraminifer *Miliola*. This stone is also called Porbander stone and is used for building purposes in Kathiawar. It attains a thickness of 100 feet in Western Kathiawar. This Miliolite limestone of the Recent age is found on the top of the Chotila hill, 1,173 feet in altitude. This furnishes a very lucid proof of the elevation of the coast within the Recent times. Besides, there occur also raised beaches, oyster beds and coral reefs on the coast of Kathiawar, which has undergone upheaval to an extent of a few hundred feet since the Pleistocene period.

It may be observed that the lowlying area, which links the Kathiawar peninsula with the mainland near Ahmedabad, is composed of Recent deposit, shewing thereby that this was an estuarine area during the Pleistocene.

Along the coast of Malabar and Travancore mud banks, which are of Pleistocene to Recent in age, have been

built which separate backwaters or *Kayals* from the sea. These backwaters furnish an important means of communication by small craft.

Raised beaches, with molluscan shells of even living species and 50 to 100 feet in height above present sea level are found at several places along Orissa, Nellore, Madras, Madura and Tinnevelly on the east coast. They definitely point to an emergence of the coast at least to an elevation of 50 to 100 feet.

Advance of Coast Line :—There is indubitable evidence that the land has gained on the sea within the Recent or historical times. This is particularly true in the region of the deltas of some of the important Peninsular rivers. For example, Kallingapatnam at the mouth of the Godavari, Kaveripatnam in the delta of the Cauvery, and Korkai on the Tinnevelly coast were all prosperous sea ports, about 1,000—2,000 years ago but now occur some miles inland, as a result of the advance of the deltas on the sea. Likewise the Rann of Cutch has also become dry land within the Recent times.

Encroachment of the Sea :—In contrast to the above the sea has encroached upon the land in several places. A notable testimony of this phenomenon is to be observed at Tranquebar on the Tanjore coast where the ruins of a Pagoda were to be seen above low water-mark even during the last century. Similarly, the San Thome town, which is now a part of the city of Madras, is alleged to have been some distance inland but now lies on the sea-shore. The sea is also making vigorous inroads on the northern part of the city of Madras and costly protective works were found necessary to check this incursion. It is, however, partly to be attributed to the construction of the artificial harbour of Madras, as the coastal current flowing past

the pier, whirls in towards the land on the northern side of the harbour.

Islands and Archipelagoes

There are a number of islands lying off the western and eastern coast of India. Those off the western coast are important and will be dealt with first.

Laccadive Islands:—These islands occur at a distance of about 125 to 200 miles off the west coast of India between lat. 10° and 12° North and long. 71° 40′ and 74° East. The name Laccadive literally means a hundred thousand islands, which are believed to lie on the submarine ridge which represents really an extension of the Aravalli mountains to the south. These islands have emerged mostly from the eastern, *i.e.*, the protected side of the reef; the western side is fully exposed to the monsoon from the Arabian Sea. These atolls or coral islands may be divided into two groups: the northern and the southern. These are low-lying islands and are covered by cocoanut plantations. On the islands various food-grains, pulses, bananas and vegetables are grown. The islanders, however, depend for their living mainly on cocoanuts and their products which are sold on the mainland of the west coast. The manufacture of coir is the chief industry.

The Maldive islands are believed to be volcanic in origin, in contrast to the Laccadive islands, and are under the administration of the Government of Ceylon.

Pamban Island:—This island, which means snake island, derives its name from the tortuous character of the channel which separates the island from the mainland. There is testimony to show that there was a former link between the mainland and Ceylon. This is represented by the Adam's Bridge and the island of Manaar on the Ceylon coast and that of Pamban on the coast of India.. The latter

is about eleven miles in length with a maximum width of six miles. Towards the eastern end there is a strip of sandy area with sand-dunes which extend towards the Adam's Bridge. The vestiges of a causeway extending from the mainland to the island are still visible. A coral reef fringes the north coast. The railway line extends across the island to the farthest point of Dhanushkodi and there plies a steamer between this point and Colombo.

Hare Island :—This island, which is fringed by coral reefs, is 2½ miles from Tuticorin. Game such as hare is available on this island.

Sriharikota Island :—This island has been mentioned already in connection with the lake of Pulicat. This is a low-lying island, 35 miles in length. It lies off the coast of Nellore and is bounded on the west by the Pulicat lake and on the east by the Bay of Bengal. The island is forested and is an important source of firewood for Madras.

CHAPTER IX

VOLCANOES

There are hardly any active volcanoes at present in India but volcanic activity was rife at different times and places in the earth's history of India (See Fig. 6). The earliest known volcanic eruptions occurred at several centres in Peninsular India in the Dharwar times of the Archæan Era. The most well-known centre of this period was the Dalma range in Bihar. The volcanic phenomenon manifested itself next in the Cuddapah period. Contemporaneous eruptions occurred at widely distant centres like the neighbourhood of Cuddapah in the Madras Presidency, Bijawar and Gwalior in Central India. The next important period, when volcanic eruptions occurred on a gigantic scale, was in the Vindhyan times. Malani is a well-known centre in the Aravallis and it is considered that its northern equivalents occur some 240 miles to the north in the plains of the Punjab.

The succeeding record of volcanic activity is preserved in the Kumaun Himalayas in the interesting lake region of the Naini Tal district. These eruptions extended from the neighbourhood of Bhowali to the Bhim Tal, and beyond. In the Upper Carboniferous times Kashmir was a great volcanic region. The activity commenced with explosive eruptions, but it yielded later on to the quiet upwellings of lava. The records of this volcanic activity are to be seen in the Pir Panjal Range, Ladakh, Baltistan and as far north-west as Hazara. This activity finally ended in Upper Triassic times.

The Jurassic period in India was another important epoch when volcanic activity manifested itself in the Rajmahal hills and the Abor hills of Assam.

The extent of volcanic activity during the Deccan Trap period has absolutely no parallel in the geological history of this country. Fissure eruptions became active sometime at the close of the Mesozoic or the beginning of the Tertiary Era, and these lavas, in places, are about 7,000 feet in thickness, and occupy today an area of 200,000 square miles; but if the detached outcrops, found as far as Sind and Baluchistan, are included, its original area would cover nearly half a million square miles.

Important, recently extinct volcanoes occur in Baluchistan, and these are only an easterly continuation of those in Iran. These volcanoes have a great economic importance, as the escaping gases from them have laid sometimes large deposits of sulphur, which, apart from its strategic importance, finds essential use in many important industries. It may be noted that when supplies of foreign sulphur were not available, India had to fall back upon the sulphur deposits of Koh-i-Sultan, etc. They also contain sulphate of alumina, which is extracted and used as a mordant.

Dharwar Volcanic Activity

Dalma Range :—The earliest volcanic activity, records of which are to be seen in North Singhbhum in Bihar, was rife in the Dharwar period of the Archæan Era, about 1,000 million years ago. At this time, huge volcanic outbursts of basaltic lava flows, tuffs and volcanic breccia occurred which are to be seen in the Dalma range, situated to the north of Jamshedpur. The lava flows occur in two belts with an east-west strike. Similar volcanic rocks have been found south of Chaibassa.

Purana Volcanic Activity

Cuddapah Volcanic Activity :—The next period, when volcanic activity manifested itself was during the

early Cuddapah period. Volcanic eruptions, ejecting basaltic lavas and tuffs, occurred near Cuddapah in the Madras Presidency. The dyke representatives of the lava flows also occur in these rocks. It is remarkable that the barytes and asbestos deposits occur at the junction of the dolomitic limestones with these traps. Similar basaltic lavas of approximately the same age have been found at Bijawar in Central India and near Gwalior.

Volcanic Activity in Gwalior:—In the Gwalior State in Central India, several occurrences of the trap are known, which is both of effusive and intrusive origin. Near Bela and Chaura, definite dark grey basaltic lava flows, which are fine-grained, occur. Near Bela, two localities, where definite volcanic eruptions have occurred, are near Bauri and the south-west of hill of Raipur. Similarly, near Chaura three old volcanic centres are known; the first is a mile north-east of Chaura where the trap attains a thickness of 25 feet. Secondly, a hill to the south-east of the temple near Chaura is built exclusively of basaltic lava. The third locality is near Nayagaon where trap with a sphæroidal weathering is seen to extend for 2½ miles; the maximum thickness is 70 feet. The hypabyssal roots of these traps in the form of dolerites also occur in several places in these hills and these are more coarse-grained than basalts. These lavas are roughly 500 million years old.

Malani, Jodhpur, Rajputana:—In the Lower Vindhayan times, Malani near Jodhpur was the scene of extensive volcanic activity, when acid ryholite lavas, tuffs, and volcanic breccia were poured forth over an area of about 17,000 square miles. They extend for 145 miles from east to west and for 120 miles from north to south. The lavas are the predominant rocks with intercalations

of thick beds of tuff and breccia, which are subordinate in amount. Thus there were quiet upwellings of lava along with explosive eruptions. The lavas have a varying colour and texture, the most common colour being brown. The lavas show a well-developed flow and vesicular texture. They present an uneven scoriaceous surface of the flows and owing to the viscous character of the lava the flows die out abruptly. Some of the flows, however, are of considerable thickness and appear to continue for several miles; but thin sheets, with varying colour and texture, are quite common.

Son Valley :—In the Lower Vindhyan period, between Japla and Kutumbeh occurred one of the volcanic centres, which erupted true lavas and rhyolitic tuffs of varying coarseness. As the tuffs predominate, the eruptions occurred under subaqueous conditions. They have undergone secondary silicification.

Kirana Hills, Punjab :—In the Kirana group of hills which rise abruptly with a N.W.—S.E. strike from the plains of the Jech and Rachna *doabs* of the Punjab, evidence of volcanic activity is preserved in the form of rhyolite and tuffs and green or reddish-coloured basalts or andesites with dolerites and quartz dolerites. Likewise in the Chiniot hills, which form narrow interrupted ridge with a W.N.W.—E.S.E. direction across the Chenab river, volcanic tuffs and agglomerages are to be seen. It is noteworthy that they are believed to be contemporaneous with Malani rhyolites, described above. It is considered by A.M.Heron, who investigated this area, that the volcanic activity seems to have diminished towards the north.

Palæozoic Volcanic Activity

In the Himalayas there are many localites, where volcanic activity was rife during the Palæozoic Era, the most

important localites being those of Kashmir and the neighbourhood, Dalhousie area, Sutlej valley north of Simla, Lobah in British Garhwal and Bhowali-Bhim Tal area in the Naini Tal District. Some of these areas are rather difficult, and not easy of access, and have not therefore been fully investigated; but the authors who visited them were of the opinion that the volcanic eruptions were contemporaneous. Commencing from the east, we have the Bhowali-Bhim Tal region in the Naini Tal district of the Kumaun Himalaya.

Bhowali and Bhim Tal Regions:—The Kumaun Himalayas, particularly the Bhowali and Bhim Tal regions, were great volcanic centres in the Palæozoic Era. While proceeding from Naini Tal towards Bhowali, agglomeratic slates occur near the village of Bhumia Dhar. At Bhowali itself, several varieties of altered basic lavas are to be seen. These volcanic rocks extend farther and are to be observed in the neighbourhood of the Bhim Tal. They attain considerable thickness on the eastern side of the lake, and extend as high as the village of Saungaon, while on the other side quartzites are to be observed at a short distance from the lake. These lavas appeared to have flowed over the quartzites, and comprise basalts of greenish, brownish or dark grey colour, and include the mugearite variety. These lavas are highly altered and, in places, dolerite or even rocks approaching gabbro occur. Towards the south, *en route* to Ranibagh, granite has intruded into the basalts, and the former is seen contaminated with inclusions of the basic lava.

It is surmised that, by the building of the barrier of the Dungsil hill, etc., at the lower end of the lake, the Bhim Tal originated. By one of the later eruptions, a breach was caused, through which the Bhim Tal *Gadhera*

finds its present exit. A study of the one-inch map-sheet of the region shows the lower deserted course of the Nauli *Gadna* (which represents an inlet into the lake), which it must have followed before the volcanic eruptions forming the hills at the southern end.

Lobah, British Garhwal :—Proceeding to the district of British Garhwal, there occurs the Lobah volcanic region. Here, lava, contemporaneous with gneissose granite, occurs. Farther south near Suini, proper rhyolitic rocks are found which include several varieties of compact and slightly vesicular types.

Another set of acidic lavas are found along the ridge, north-west of Dudatoli massif and three miles west of Dobri trigonometrical station. They are believed to be of the same age as the Lobah flows. The intermediate and basic flows are also associated. C. S. Middlemiss correlated these rocks with those of the Bhowali-Bhim Tal area, described above.

Sutlej Valley :—In the Sutlej Valley, volcanic rocks, associated with the Infra Krol rocks, occur at several localities. They comprise basaltic lava flows, which are sometimes amygdaloidal, with associated ash beds, which may be impure as they were deposited under sub-aqueous conditions. Sometimes their hypabyssal representatives, dolerites, also occur.

Dalhousie, N. W. Himalaya :—In this area, a large thickness of trap is found with a faulted contact with the Tertiary rocks. The lavas are greenish-grey in colour and possess both compact and amygdaloidal texture. They attain great thickness between Nagali and Kandao and they also occur at the boundary of the Chamba and Kashmir States. C. A. McMahon correlated these rocks with the Panjal trap.

Pir Panjal Volcanic Activity :—After a long quiescence volcanic activity burst forth in the Upper Carboniferous times in Kashmir and continued for some time. The Panjal volcanics are composed of two members, lower and upper, *viz.*, (*i*) the Agglomeratic slates and (*ii*) the Panjal trap.

The volcanic activity commenced with a strong explosive phase, when the Agglomeratic slates of pyroclastic origin were deposited. This was followed by the quiet upwelling of the lava, when an enormous thickness of bedded and massive lavas, greenish, purple and dark-coloured, and comprising flows of basalts and andesites, with some trachytes and rhyolites, was deposited. These lavas are both amygdaloidal and compact in character. Both the members occur together over a large area of Kashmir and are well-developed in the Pir Panjal Range. But this volcanic activity also manifested itself in Ladakh and Baltistan and even as far as Hazara. The volcanic activity, as noted above, commenced in the Upper Carboniferous times. It is believed to have reached its climax in the Permian and died off gradually in Upper Triassic times.

These lavas have furnished good building stone and road metal.

Hazara District :—In the Hazara district, vestiges of volcanic activity occur in the form of devitrified acid lava, about 50—100 feet in thickness, which is overlaid by a thick formation of limestone with Upper Triassic fossils. The lava is believed to have been originally a rhyolitic flow.

Mesozoic Volcanic Activity

Rajmahal Hills :—The Jurassic period of the Mesozoic Era, *i.e.*, approximately 150 million years ago, is well-known for its volcanic manifestations. Volcanic eruptions

occurred at this time in several parts of India. The Rajmahal hills formed one of the important centres and here a pile of very fine-grained and tough basaltic lava, about 2,000 feet in thickness, with some inter-trappean beds, is to be observed. In the inter-trappean rocks, silicified trunks of trees are abundant; the majority of these vary from one foot to 18 inches in diameter, while some have a diameter of three to four feet. In places the rock seems to be composed almost entirely of small stems or twigs. In the north-eastern extremity of Upper Assam, basaltic lavas, called the Abor Volcanics, described below, were poured forth at the same time.

Abor Volcanics :—A considerable development of greyish, greenish or reddish basaltic trap is to be seen in the Abor hills in the Eastern Himalaya. Contemporaneous volcanic bands are to be seen interbedded with Godwana rocks between Renging and Upper Rotung. In the Dihong river excellent exposures of massive lava flows, dark-green and dark-reddish in colour, are to be seen. In places these lavas are amygdaloidal. The Gondwanas are composed of hard, white and reddish-white massive quartzites, carbonaceous shales and sandstones. Sometimes the shales have been hardened by thermal metamorphism and developed a new jointing perpendicular to the bedding plane.

Sometimes variegated volcanic ashes, reddish, greenish and mottled-red in colour, occur. Agglomerates are also associated. This shows that the volcanic activity in places was of explosive character.

These rocks show a remarkable similarity to the Rajmahal traps. The mode of occurrence of these volcanic rocks, associated with the Gondwana deposits, is also similar.

Deccan Trap Volcanic Activity

Towards the close of the Mesozoic and the beginning of the Tertiary, India, particularly Western and Central India, was the scene of unprecedented volcanic activity. Basaltic lavas, about 7 to 10,000 feet in thickness, were deposited, forming a huge plateau, a description of which has already been given in Chapter III. Some outlying patches of these lavas are to be observed in Sind, Baluchistan, etc.

Kashmir :—The Burzil valley of Kashmir was the scene of volcanic activity during the Cretaceous period, when basaltic lavas were again poured forth. Quiet upwelling of the lava was accompanied by highly explosive eruptions, which were responsible for the deposition of volcanic agglomerates in this area.

Salt Range :—In the eastern part of the Salt Range volcanic activity was rife at a few centres; those of the Khewra glen and the Nilawan ravine deserve mention. In the Khewra gorge, a purplish lava is seen to be embedded in the Saline series. It is noteworthy that after the volcanic eruptions, hydrothermal activity followed, when the superheated waters silicified the gypsum, the dolomites and the oil shales associated with the Saline series.

Baluchistan :—Evidence of submarine volcanic activity in Upper Cretaceous to Eocene times is to be observed in some of the ranges in Baluchistan. These volcanic hills are conspicuous on account of their dark colour and great altitude. Basic lavas, volcanic agglomerates, tuffs and ashes are found interbedded with the marine sediments. Underground representatives of these rocks, in the form of columnar diorite, occur in the neighbourhood of Ladis and Tozgi. Basic igneous intrusions of serpentinised rocks, representing roots of these volcanoes, which have now been

laid bare by denudation and upheaval, also occur, especially in the Jhalawan area of Baluchistan. Chromite occurs associated with these intrusive rocks. These volcanic deposits, however, have an irregular distribution in space and time but the evidence shows that the eruptions were most active in Upper Cretaceous, contemporaneously with the great Deccan Trap volcanic activity in Peninsular India.

This Upper Cretaceous volcanic activity appears to have been very widespread as evidence of these eruptions is not only to be found in Western and Central India and in Baluchistan, but is definitely known to extend even as far as Iran.

Siwalik Volcanic Activity :—According to E. Vredenburg, volcanic rocks, interbedded with the Siwaliks, occur on the right bank of the Robat river, near Pain Robat. He concluded that the great volcanic eruptions, which in Recent and Sub-Recent times built the gigantic volcanoes of Koh-i-Sultan, Damodin, etc., in Baluchistan and Koh-i-Taftan, etc., in Eastern Persia, had already begun activity in the Siwalik times.

Recent Baluchistan Volcanoes

In the desert of Baluchistan occur the recently extinct volcanoes of Koh-i-Sultan, Damodin, etc.

Koh-i-Sultan :—The volcano of Koh-i-Sultan is oval in shape, and its length in a W.N.W. direction is 17 miles, while the width is about 10 miles. It is believed to be a recently extinct volcano, and the centre of activity apparently shifted several times, with the result that three distinct cones are found, occurring in one straight line. These three cones, the western, the central and the eastern one have

undergone great denudation. The latter contains the highest summit of the mountain called the "Miri" which is 7,656 feet in height above sea level.

The volcano, as stated above, in its decadent stage has a solfataric phase, and in the eastern portion, particularly round the "Miri", the deposition of sulphur is most marked. Similar deposit has been observed further west. It has already been noted that, when supplies of foreign sulphur were cut off, India had to fall back upon the sulphur deposits of Koh-i-Sultan, etc.

Damodin :—The volcano of Damodin occurs to the west of the Koh-i-Sultan and its shape is that of a truncated cone, 4½ miles in width. The explanation of the shallow crater is somewhat difficult. On the west and the north of this elevated plain, there are steeply sloping summits, while, on the south and east, the rim is bounded by very low hills. The three peaks on the west and the one on the north are built of lava, while the remaining portion of the crater is composed of agglomerates, similar to those of the Koh-i-Sultan. It is considered that the last eruption of the volcano was explosive which may have produced this shallow crater. Owing to very dry climate of the region the crater was not filled with the lake but as a result of denudation, it was transformed into the shallow circular plain as seen at present. The rocks of the eastern slopes of the Damodin have been affected by the same solfataric action as in the case of the Koh-i-Sultan.

Smaller cones of Recent date, built entirely of lava, are to be found in the vicinity of the Koh-i-Sultan. They are of a younger age than the volcanoes of the Koh-i-Sultan and Damodin. When unaffected by denudation, they have a roughly hemi-spherical outline. The lavas are believed to have poured forth in a viscuous state and con-

solidated with steep slopes, without having flowed for any distance. E. Vredenburg, who investigated these volcanoes, compared them to the Puy de Dome type of hills in Auvergne in France.

Batil Koh :—It is smaller in size than Puy de Dome and occurs on the southern talus of the Koh-i-Sultan. The volcano is of a very recent date and rises on the ridge between two of the valleys. Fragments of the talus boulders were observed to have been caught up in the Batil Koh lava.

Koh-i-Dalil :—This volcano is of the same size as Puy de Dome, or it may be even slightly bigger. It is about 15 miles east of Damodin and its structure resembles that of Batil Koh. It forms an important landmark in the neighbourhood. The upper surface of the lava presents a scoriaceous appearance. Fresh lava is grey in colour while the altered rock has a brick-red appearance.

Mit Koh :—This volcano occurs to the north by east of Amir Chah which is separated by a broad belt of sand-dunes from it. It is conspicuous on account of its isolated position and has red colour. It has undergone greater denudation than the Batil Koh and Koh-i-Dalil and this has affected its regular hemi-spherical shape. It is noteworthy that these volcanoes form an easterly extension of an important volcanic region occupying a large part of Eastern Iran.

Important Volcanic Belts

It appears to the author that the ancient volcanic centres of India are distributed along certain well-marked lines or belts and at least the following seven important ones deserve mention (See Fig. 6); there may be other subsidiary ones :—

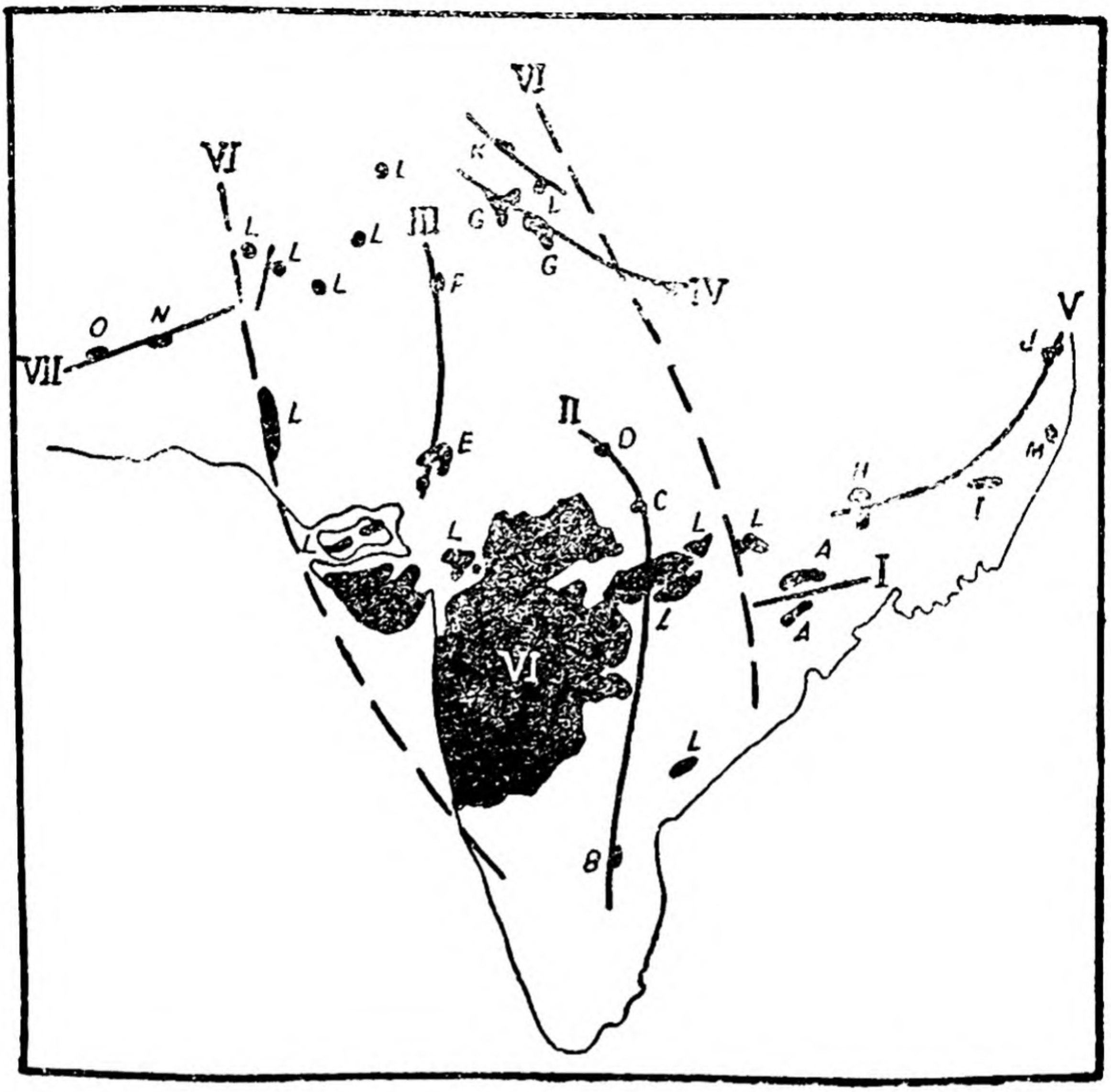


Fig. 6—Showing the distribution of old volcanic centres in India. It also depicts important volcanic belts.

A. Dalma Trap, Bihar; B. Cuddapah Trap; C. Bijawar Trap; D. Gwalior Trap, Central India; E. Malani Rhyolites, Rajputana; F. Kirana Hills, Punjab; G. Panjal Volcanics; H. Rajmahal Trap; J. Abor Volcanics; K. Burzil Valley, Kashmir; L. Deccan Trap; M. Manipur; N. Koh-i-Sultan, Baluchistan; O. Koh-i-Taftan, Iran.

(1) The first line represents the two belts of the Dalma Trap in Bihar, which follow an east-west direction.

(2) The second belt comprises the Cuddapah, Bijawar and Gwalior Traps.

(3) The third line passes through Malani near Jodhpur and the Kirana hills, etc. in the Punjab.

(4) In all probability the trap rocks of Naini Tal, Bhowali, Bhim Tal, Lobah area in British Garhwal, Sutlej Valley, Dalhousie area and the lavas of the Pir Panjal belong to the same belt. The association of agglomeratic slates, at either end further supports this conclusion.

(5) Next is the important Jurassic line which connects the Rajmahal trap and the Abor volcanics.

(6) The most extensive belt of the Deccan trap occupies a vast area and has detached outcrops. The Cretaceous volcanic rocks of Sind, Baluchistan and the Burzil valley apparently belong to the same belt.

(7) Finally may be mentioned the belt of recently extinct volcanoes in the desert of Baluchistan. These, of course, extend to Iran in the west.

In a treatise of this kind only a preliminary and brief idea of this subject can be given.

Economic Importance of Volcanic Districts

Some of the volcanic regions are economically very important; for instance, the Koh-i-Sultan area, which, as already noted, contains important deposits of sulphur. It is, no doubt, true that these deposits saved a very awkward situation during the War, when supplies of foreign sulphur were not available. Secondly, volcanic rocks are generally hard and therefore provide good building stone and road metal. The Gateway of India is built of a light-coloured volcanic rock from the Salsette island of Bombay. But the most beneficial value of volcanic rocks, particularly the intermediate and the basic lavas, is that they yield fertile soils and are thus very valuable to the cultivator. The author, as a result of his studies in different tracts of India, Burma and elsewhere has been fully convinced of this fact.

While working in the Kumaun Himalayas he found that every inch of the trap rock in the neighbourhood of the Bhim Tal lake was under cultivation and in fact the limit of cultivation indicated the extent of the trap rock. The fertile nature of the Black Cotton Soil, derived from the Deccan Trap, is well-known. Likewise, the author observed the same fact, while studying the Mount Popa region in Burma. This volcano rises on the Irrawaddian sands and the fertile character of the soils of the intermediate and basic lavas, indeed, presented a great contrast to the adjoining sandy soils. There is a breach in the volcano on the north-west and consequently one can walk into the former crater area. The local villagers here would simply broadcast the seed, which would take root even in the crevices of the rocks and yielded very good harvests.

Mud Volcanoes

It should be clearly understood that the 'mud volcanoes' have nothing, whatever, to do with the true volcanic phenomena and that the name 'mud volcanoes' is a misnomer. It is now definitely established that they owe their origin to the escaping gas associated with petroliferous strata.

Two types of mud volcanoes can be recognised by shape, *i.e.*, (*i*) basins and (*ii*) cones, though sometimes it is very difficult to distinguish one from the other. The basins are more or less circular or elliptical holes in the ground. When active, they are filled with muddy water, and the incessant escape of small gas bubbles gives the liquid the appearance of boiling, also producing gurgling noises. Some of these vents are permanent, while others are only temporary, the vent becoming clogged. Fresh gas bubbles then begin to rise at another place. Petroleum is brought up with the gas and forms more or less a continuous film on the surface of the water.

The second type, cones, are built up of mud ejected from the vent and commonly possess steep sides with a crater in the centre, sometimes with a diameter of several feet. It is interesting to observe that sometimes parasitic cones or secondary vents appear on the sides of a cone. If the pressure of gas is sufficient, the mud will overflow the rim of the cone and give rise to streams of mud. These cones may sometimes become extinct and then become active again with even greater vigour. These mud volcanoes produce a greyish-blue mud of varying consistency, more or less staturated with petroleum and an inflammable gas.

In the Dhulian oil-field area in the Rawalpindi district of the Punjab, two or three mud volcanoes or salses occur which eject small quantities of gas and saline water.

On the Mekran coast of Baluchistan, there occur mud volcanoes which are connected with petroliferous strata. Petroleum gas escapes with mud and water and builds mounds, some of which in this dry climate, attain a height of about 300 feet, which is considerably greater than the elevation of mud volcanoes in Burma. In Burma, the wet climate, *i.e.*, the showers of rain tend to lower the altitude of these mud volcanoes.

CHAPTER X

HOT SPRINGS AND MINERAL WATERS

It is generally not familiar how springs of various kinds play an important rôle in the national economy of a country. There may be fresh-water springs, salt or brine springs, hot springs, sulphurous springs, siliceous, chalybeate, calcareous, magnesian or medicinal springs and springs which yield beneficial table mineral waters. Springs often form the sources of rivers, *e.g.*, the Jhelum in Kashmir valley takes its rise from Verinag and other springs. Springs are sometimes the only sources of water supply in the neighbourhood. It was observed that the villages situated in the neighbourhood of Simla obtain their drinking water from the adjoining springs, while the water of the streams gets polluted by the work of washermen, etc. Bathing in hot springs is often beneficial in maladies like rheumatism, while the sulphurous springs can be helpful in curing diseases of the skin. Some hot springs deposit precious metals like gold with their sinter. There are other medicinal springs containing alkaline iodide which can be efficacious in curing diseases like goitre. The waters of some of the springs are highly radio-active. Waters of some of the springs are powerful enough to turn the wheels of several mills. The water of some of the springs is used for irrigation purposes in the Himalayas and other hills in the country.

Occurrence of Springs:—Before a study of the springs of India is undertaken, a word about their occurrence and cause of appearance may be mentioned. Most of the springs issue forth as a result of two causes: firstly the impervious strata underlies the pervious one and the water, being not able to travel any further, makes its

appearance on the junction of these two rocks. Secondly springs manifest themselves along fault lines. These faults or fissures may mark the junction of two different strata, *e.g.*, the hot springs of the Kopili river in Assam occur at the junction of the Cretaceous and the Nummultic rocks, as described below. Hot springs, sometimes emanating gases, sulphur springs and sometimes even brine springs may mark the decadent phase of an igneous activity. Water, in its passage through rocks, may dissolve some of their chemical constituents or it may bring its chemical constituents from subterranean sources.

The hot springs of India are found associated with rocks like granite, gneiss, trap, matamorphic rocks, the boundary of the Cretaceous and the Nummulitics and the Nummulitic rocks alone. Obviously the fissures in the above rocks provide passage for the ascent of hot water from below, which manifests itself as a result of some decadent igneous or thermal activity. It is not improbable that the hot springs, so commonly associated with the Nummulitic rocks of Extra-Peninsular India, mark the decadent phase of the Deccan Trap volcanic activity, the most active phase of which concluded about that time.

Sulphurous springs are more commonly associated with rocks containing gypsum, iron pyrites, alum or other compounds containing sulphur.

The mineral waters of this country have not been utilised for commercial purposes to the same extent as those of Europe and Japan. Thomas Oldham has published a list of 300 hot springs. LaTouche in the year 1918 added another 48 localities, stating that the list was not exhaustive. It has been stated above that waters of some of the hot springs are radio-active but radio-therapy, which is practised on such a large scale in Europe and elsewhere is practically unknown in India.

N.W.F.P.

Kohat District :—Sulphur springs occur associated with the upper zones of the Nummulitic limestone and clays on the right bank of the Indus near Dandi hill station. Here ruins of large works for sulphur or alum are to be seen.

Sulphur springs are also stated to be issuing from solid limestone in the Ungo pass.

Sulphurous springs also occur associated with the salt deposits of the Kohat region in the Algud stream. They yield saturated brine and hydrogen sulphide gas. Apparently these springs derive their salt from the salt deposits and hydrogen sulphide gas by the decomposition of iron pyrites which is present in the salt and the associated clays.

Hazara District :—The Margalla hills form the southern border of the Hazara district. It is remarkable that "about a dozen sulphur springs, including dry seepage of sulphuretted hydrogen gas occur along the southern margin of the Margalla.* In a majority of cases they issue either from the upper Nummulitic gypseous shales or are closely associated with them.

Sind

In the Tertiary rocks of Sind and Baluchistan hot springs occur, which are often sulphurous in character. The line of these hot springs begins near Karachi and it extends in a northerly direction. The springs of Baluchistan are situated on an elongation of this line.

Mangah Pir :—The springs known as Mangah Pir or Magar Pir issue forth just above the base of the Gaj† beds. There are two separate springs and the highest

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* *Rec. G.S.I.*, Vol. 60, 1927, p. 104.

†For explanation of such terms, a reference may be made to chapters on Geology.

temperature given by T. Oldham is 127°F. The temperature of the hotter spring of the two, as determined by the Rev. Sierp in April, 1912, was 112°. It probably represents the hottest spring in Sind. The water of this spring is radioactive and being near Karachi it is visited both by Indians and Europeans.

Laki Spring :—North-west of the town of Laki or Lakhi in the Larkana district there are two springs but the larger one issues from the base of a calcareous precipice, about 600 feet in height, and is locally known as the Dhara hill. It has a moderately copious discharge and it is alleged that it emits the largest quantity of sulphuretted hydrogen of all the springs in the province. By oxidation of the gas sulphur is formed and is deposited in places where the flow of the water is limited. The temperature of water is given as 40.8°C, which is radioactive. It is believed to be efficacious in cases of skin diseases and rheumatism and they are visited by a large number of people. It deposits calcareous tufa.

Shah Ruhi Spring :—There is a large hot spring at Shah Ruhi with a temperature of 100°. It has laid thick deposits of calcareous tufa and the water is employed for irrigation.

Pir Ghazi Spring :—Near Pir Ghazi, a Mohammedan shrine, a very fine hot spring issues forth from the base of the Nari beds. It has deposited enormous quantities of calcareous tufa.

Lakha Pir :—About six miles south of the termination of the Kirthar range, the hot spring of Lakha Pir with a temperature of 112°F rises in a valley. It has a strong smell of sulphuretted hydrogen and the country rock is Nummulitic limestone. The spring occurs on an important fault which extends for 40 miles to the south.

Baluchistan

Spintangi :—The local Baluchi name for this spring is Gaureji, which is a railway station on the Sind-Pishin branch of the North Western Railway. It derives its name Spintangi from a white valley through which the stream flows. At least seven springs occur and the largest has a copious discharge and the water gushes out with some force. All the springs are strongly sulphurous and the smell of hydrogen sulphide gas fills the whole valley. The temperature was determined to be 34.8°C. All these springs are highly radioactive. This spring is visited by Europeans.

Kashmir

Vale of Kashmir :—Near the village of Wian in the district of Vihi and to the south-east of Srinagar three sulphurous springs, called *phuk nag*, with a high temperature issue from limestone.

Islamabad :—Two well known sulphurous springs issue from the limestone rock at the back of the town.

Wardwan Valley :—In this valley of Kashmir State, and near the village of Maru and up the Farriabadi river above Kishtwar, the country rock is composed of the gneiss. Lydekkar has recorded that "several boiling and sulphurous springs occur about ten miles up the Farriabadi river and also in several other places of this district."*

Baltistan :—In Baltistan several thermal springs occur of which the following are important. The hot spring of Bisil lies on the Basha river and has a temperature of 160°F. The hot spring of Chitrun occurs lower down on the same river and perhaps represents the largest hot spring in the region. Its temperature is given as 110°F.

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* *Rec. G.S.I.* Vol. XI, 1878, p. 51.

It rises in two jets from fissures in the gneiss. It emits a strong smell of sulphuretted hydrogen and deposits travertin. It is reputed for medicinal properties in Baltistan.

The hot springs of Tosho, Hoto and Chongo occur on the Braldu river. The latter is a large sulphurous spring with a temperature of 169°F.

The hot spring of Khorkhun is near the village of the same name and occurs on the Kondus branch of the Saltoro river which is a tributary of the Shyok river. Its temperature is given as 185°F.

Ladakh :—In Ladakh, two hot springs occur about 13 miles up the Nubra river near the village of Panamik. The temperature of water is 170°—172°F and the springs are sulphurous and deposit travertin.

Puga Valley :—On the Puga river, a tributary of the Upper Indus, numerous hot springs with a maximum temperature of 174°F, occur. These springs are noted for their deposits of borax. The region may produce about 4,000 maunds of borax and 500 maunds of sulphur annually.

Poonch

Tatta Pani :—In the State of Poonch, there is a hot sulphurous spring, known as Tatta pani. There is a copious discharge of water which has a temperature of 190°F.

Saira :—Near the village of Saira above Kotli a thermal spring occurs above the left bank of a stream which runs into the Poonch river.

Rajaori :—One march eastward of Rajaori, a hot spring with a temperature of 140°F occurs. It is sulphurous in character. A cold spring issues close by.

Sikkim

A number of hot springs occur in Sikkim and some of the important ones are described below.

(*a*) **Phut Sachu :—**This spring issues from dark coloured massive siliceous limestones on the east side of the Rangit river, about two miles north-east of Rinchinpong monastery. Hot foetid water with a temperature of 100.4°F bubbles up in several places.

(*b*) **Ralong Sachu :—**It rises at an elevation of 3,100 feet above sea level, from finely laminated phyllites with abundant vein quartz on the west bank of the Rangit river, about two miles north-north-west of Ralong monastery. Hot water flows through fissures from several spots and the highest temperature was observed to be 131°F. It is also the highest temperature for this group. But in a reservoir built for bathing, the temperture was only 118.4°F, the temperature of water of an adjoining stream being only 53.6°. It has deposited a whitish calcareous material which is stained green with carbonate of copper, owing to the water passing through copper-bearing rocks.

Another hot spring occurs about half a mile north of Ralong Sachu.

(*c*) **Yeumtong :—**A hot spring on the east bank of the Lachung river and about half a mile below Yuemtong river has a discharge of a few gallons per minute. The temperature at the exit is 112½°F while in the bath it is only 106°. The colourless water has a slightly saline taste and emits sulphuretted hydrogen gas.

(*d*) **Momay :—**This hot spring issues forth from granite about 16,000 feet above sea level and is only a mile below the Kinchinjhow glacier. The water of the spring collects in pools and the maximum temperature observed is 116°F.

Punjab

Kulu :—Indians, particularly the Hindus, have recognised the value of some of these springs and they have become places of pilgrim resort. The hot springs at Manikaran in Kulu, where the pilgrims boil their rice in the hot springs issuing from the shingle bed adjoining the ice-cold waters of the Parbati river, provide a notable example. The hot water is also led into the neighbouring temple and is believed to be efficacious in cases of rheumatism.

Yellow calcareous tufa is deposited by these springs and they also eject small white, pearl-like beads or *manis*, which are treasured as ornaments or souvenirs. The springs also exhale sulphuretted hydrogen and impart a reddish brown stain to the drains, baths and the adjoining rocks.

Kangra :—The springs of Jwalamukhi in the Kangra district contain an alkaline iodide and are efficacious in cases of goitre.

Sutlej Valley :—Below Suni in the Sutlej valley, to the north of Simla, a hot spring has a copious discharge in the very bed of the river. The locality no doubt marks an area of great local movements which were accompanied by igneous intrusions and extrusions of much trap.

Rajputana

Although several hot springs issue from Rajputana hills, but only a few, described below, are of any interest.

Sohna :—This spring is about 33 miles south of Delhi and about 15 miles from Gurgaon. It rises near one of the most craggy and precipitous parts of the ridge at an elevation of about 800 feet on the eastern face of the Mewat hills. The water, which emits a strong smell of sulphur, has a temperature of 125°F. It also gives off sulphuretted

hydrogen gas. The well or basin, into which the spring rises, has been excavated 16 feet square and about 30 feet in depth.

The second important spring is Talbrich which is about 15 miles west by south of Alwar. The temperature of the water is given as 118°F.

Naraini Spring :—The third is probably the well-known Naraini spring, which is 2½ miles W.N.W. of Baldeogarh. It lies in the Alwar State about 35 miles E.N.E. of Jaipur. The discharge is stated to be copious and the water is tepid, which collects into a bathing tank surrounded by the temples. The spring is held in particular reverence by the people of the barber caste.

Gwalior :—The Sipre spring waters in the Gwalior State have been placed on the market by a Bombay concern.

United Provinces

From these provinces, only a few hot springs have been described.. The hot springs of Gangotri and Jamnotri are, however, well-known. The occurrence of these springs at altitudes exceeding 10,000 feet above sea level, is noteworthy.

Sahasradhara :—An important sulphur spring occurs above the left bank of the stream and opposite the place called Sahasradhara, which is about 6 miles in a direct line north-east of the town of Dehra Dun. It issues forth with a copious discharge from huge blocks of dolomite, some of which are about the size of a small hut. The author found in December, 1944 that since his last visit, two small tanks for the bathing of the public had been constructed. There is a strong smell of sulphuretted hydrogen. This is evidently a deep-seated spring and by the action of these circulating solutions on limestone, the

deposits of gypsum of this area have been formed. The water of the spring, on analysis, has revealed the presence of calcium sulphate, magnesium sulphate, calcium carbonate and carbon dioxide.

Bihar

In Bihar, there are perhaps the largest number of thermal and medicinal springs, but as with the rest of India, these springs, with the solitary exception of Sita Kund near Monghyr, have not been put to any medicinal or commercial use. These springs have been classified into the following groups by L. L. Fermor, which reveal that there is evidently some relationship between the general temperature and chemical properties of the spring and the rocks in which they occur.

(*a*) **Rajghir hills :—**The springs of this belt occur at Rajghir and Tapoban and are located on the Dharwar rocks.

(*b*) **Kharakpur hills :—**Nine springs occur on this belt in the Monghyr district and they are generally located on the quartzites of the Dharwar age. They comprise Panchbur, Singhi Rikh, Tatapani, Rishi Kund, Rameshwar Kund, Bhurka, Sita Kund (about 140°), Lockmi Kund (about 144°), Janam Kund (145°) and Bhimband (about 145°). Only a slight smell of sulphuretted hydrogen is present in Sita Kund and Bhimband, otherwise all these springs are non-sulphurous in character. The springs of Sita Kund are most well-known in Bihar. There is a copious discharge of very pure water. A Calcutta firm bottled this water in making soda water. It was stated in 1794 that persons proceeding on long sea voyages carried a number of bottles of this water with them. It is also said that many people in Calcutta drank only this water.

(*c*) **Hazaribagh Belt:**—Six hot springs occur in the Hazaribagh district. Proceeding from west to east they are as follows:—Lurgurtha (160°), Pindarkun (116°), Doari (110°—115°), Suraj Kund or Kathkamasandi (110°), Belkapi (169°—190°) and Kesodih (182°). These springs are sulphurous and saline in character.

(*d*) **Santal Parganas:**—The following important springs of this region occur in gneissic rocks:—Numbil (119.5°), Tatapani (102°) and Tatloi (148.5°). These are sulphurous in character and emit hydrogen sulphide gas.

A spring occurs in Sidpur village about a mile south of the Police Station of Pakuria in the Pargana Sultanabad in the Santal Parganas. The spring has a continuous flow of warm and strongly sulphurous water which is also used by the Santals for medicinal purposes.

The springs of Baramasia and Lau-Lau-dah (122°) occur in the Rajmahal trap and the latter is slightly sulphurous. The latter occurs near Sibpur village in the jurisdiction of Mahespur Police Station. There is a copious discharge of water and gas with a faint sulphuretted smell. The water has a slightly saline taste. It has a reputation among the local people for curing itch, ulcers and other skin diseases.

Coalfields Belt:—The spring of Jarum is situated in the bed of the Taraka river, about 1½ miles north-west of Pochra. It issues forth from vertically jointed granitic gneiss. The water rises in several places and the maximum temperature is 132°F. Bubbles of sulphuretted hydrogen are given off freely and its odour is distinct near-by. The spring occurs north of Auranga coalfield.

In the neighbourhood of village Tatha, which is marked Kokraha on the map, a hot spring with a copious

discharge and a strong smell of sulphuretted hydrogen, occurs. The highest temperature is 151°F and the spring rises from a fault in the Barakar rocks in the coalfield of Hutar.

About 20 distinct hot springs occur west of Kunhur in the Tatapani field in Sirjuga. The maximum temperature is 196° and in the basins, in which springs rise, there is an encrustation of siliceous sinter. It emits sulphuretted hydrogen. Another hot spring called Gandauni occurs on the same strike and at a distance of 24 miles W.N.W. of Tatapani and 8 miles north of Partabpur. From its name, its connection with sulphur is indicated.

Three hot springs occur near Damuda in the Manbhum district. The first occurs on the faulted boundary of the coalfield below Chanch. The second, which is reputed to have a temperature of 190°F and is decidedly sulphurous, occurs on the south bank of the Damuda near the village of Tantulia. The third lies near the village of Sheodpur, near the junction of the Ghee and the Damuda rivers.

Bengal

The springs known as Sitakund near Chittagong are quite famous and are a great pilgrim resort. The various kinds of springs occurring here include hot springs, cold springs, sulphurous springs, chalybeate and brackish springs.

Assam

Kopili River :—Hot springs, which are at least seven days' journey from Silchar and two from Jawai, occur on the Kopili river. There are three springs and one lying to the south is considerably larger with a temperature of 128°. The water is tasteless, but the temperature of the other two springs is 130°. These springs lie on the

faulted boundary of the Cretaceous and the Nummulitic rocks.

Orissa

In Orissa two springs occur at Deoljhari with a maximum temperature of 134° in Athmallik State and at Atari with a temperature of 138° in the Puri district. Both these springs emit hydrogen sulphide gas and occur in the Archæan rocks of the Eastern Ghats.

Godavari Valley

In the Godavari valley there are two hot springs: (1) Gundala and (2) Bangah. The first spring is in the bed of the Godavari. On the left bank metamorphic rocks are exposed, while the right bank is composed of sandstone and the boundary is faulted. The water of the spring has a temperature of 140°F and emits sulphuretted hydrogen gas. It is buried underneath the sand of the river and in the rainy season it is covered by the river, but is visible during the rest of the year. It contains slight quantities of sulphate of soda, common salt and chloride of lime. The spring is much visited as it is believed to possess efficacy in curing skin diseases.

The hot spring of Bangah is situated about 30 miles to the north-west of Gundala. It rises in a valley from sandstones. Its temperature is 110° and from the deepest part of the pool bubbles of air or steam continue to escape. The water is tasteless and contains a little carbonate of lime in solution.

Central Provinces

Hoshangabad District:—A hot spring occurs at Anhoni Samoni in this district, where water with a temperature of 114°F issues from a trap dyke. It emits sulphuretted hydrogen gas.

Chhindwara District:—A hot spring occurs near Anhoni Dhona on the road from Chhindwara to Bankheri, which gives off inflammable gas in 10 places. The surface temperature of water is 130°F and is collected into a tank. The spring is held in high esteem by the local people.

Purna Valley, Berar:—At Salbaldi in the Purna valley of Berar, a hot spring with a temperature of 100°F occurs in the metamorphic rocks close to a fault. The water is tasteless and odourless.

Bombay Presidency

Two lines of thermal springs are known in the Presidency of Bombay. The first begins at Rajapur in Ratnagiri district and terminates at Unai in Gujarat. The second line begins at Lasundra in Gujarat, and passing through Tawa* in the Panch Mahals district, is continued on to West-Khandesh. The second line runs almost perpendicularly to the first. As noted already some of the springs are notably radio-cative.

Tawa, Panch Mahals District:—Hot springs occur at a distance of about half a mile from the railway station of Tawa. There are two springs: one cold and the other hot, the water and gas issues from numerous places and the temperature of the cold spring is 83° F, while that of hot spring is 153°F. The water of the spring is bitter and the springs are held to be sacred.

Lasundra:—These springs are about 18 miles to the W.N.W. of Tawa. They occur at about 2 hours journey by tonga from Dakor railway station on the Cambay-Godhra line. The temperature of water is 111°F.

Thana District:—There are a number of thermal springs in the Thana district which occur on a line about

*This place has been both spelt as Tuwa and Tawa.

50 miles in length. Commencing from Vajrabai in the south the line terminates at Gargaon in the north.

Vajrabai :—These springs occur in the Thana district and can be reached from Kalyan in a tonga in 4 or 5 hours. The group comprises several distinct units of hot springs which occur along and near the Tansa river. The discharge from all springs is copious and yields much gas, which is reported to have "an unpleasant smell, resembling that of rotten substances".

(*a*) The first group of springs is at Akloli where the temperature of water is about 50°C. The springs are sacred. (*b*) The second group is about a mile farther below the river. There are two springs on the bank and three in the bed of the river. The discharge is copious with emanations of gas and the temperature of water is about the same as at Akloli. (*c*) At Ganeshpuri there are two cisterns of hot water near the temple of Bhimashwar. (*d*) About a mile farther on are 3 hot springs concealed in the bed of the Tansa river. Their temperature is 137°. The discharge is copious and yields abundant gas. (*e*) The hot springs of Nimboli occur in the Tansa river to the north of Ganeshpuri. Three springs occur above the bed of the river while the fourth lies in its bed. The discharge is very copious and the temperature of water is 59°C. The spring in the river emits large quantities of gas but the springs are not sulphurous.

Sativli :—The springs of Sativli are situated near the village of the same name and are best reached from Manor, a small town on the river Vartana. The water, which is clear, has a temperature of 59.4°C. Some cisterns have been built for the use of the visitors. Large quantities of gas which is not sulphurous are given off.

Koknera :—These hot springs which are situated on the right bank of the Surya river can be reached from Palghar railway station. The temperature of water is 52°C. There is another cooler pool near-by, which has a temperature of 40°C and it emits some gas.

The Revd. Steichen and the Revd. Sierp, who examined these springs, concluded that all the hot springs are radio-active, and they contain emanations and salts of radium. The radio-activity of the hot springs at Lasundra is much greater than those of the Thana district while that of the springs at Tawa is 'quite extraordinary'. Towards the end of the dry season it was observed that the radio-activity in the case of Tawa had nearly doubled.

Unei, Baroda State :—These hot springs, which have been converted into tanks, are the most well-known in Gujarat and comprise an important pilgrim resort. The temperature is 57°C and the evolution of gas is copious but intermittent. Other springs occur in the immediate neighbourhood which have much lower temperature.

Travancore

William King gave the following generalised sequence of rocks as observed in the sea cliffs in Travancore :

Laterite
Sands or sandy clays
Alum clays
Lignite beds
Sands.

From above the alum clay band clear water springs issue at several places along the base of the cliffs. They are believed to possess medicinal properties and are therefore frequently visited by the local people. Bamboo spouts are pushed in convenient places for transporting

the water of the sacred springs. The water, passing through the alum clays and the overlying ferruginous material, has given rise to the idea that there occur natural chalybeate and other mineral springs.

Effect of Earthquakes on Springs:—The earthquakes may have an important effect on springs. It lies in widening the fissure through which the water ascends, or closing it. In the former case the discharge of water increases, while in the latter case the discharge may become markedly smaller, or the spring may die altogether. Below are discussed the effects of some of the Indian earthquakes on some well-known springs. It was observed that after the Baluchistan earthquake of 20th December, 1892, the water supply of some of the springs in the Kojak tunnel increased thus showing that the fissure, through which these springs issued, evidently became widened. With regard to the effect of the Great Earthquake of the 12th June, 1897, the Collector of Chittagong reported that the burning springs of Sitakund were abnormally active after the earthquake, while the Collector of Patna informed that from the hot springs of Rajghir discoloured water was discharged for three days.

According to Middlemiss the water supply of Jwalamukhi, which depends upon springs, was nearly doubled as a result of the Kangra earthquake of the 4th April, 1905 but the temple springs, with their natural inflammable gas were not affected.

The celebrated Manikaran hot springs of Kulu had not been affected greatly by the important Kangra earthquake. Some of them had, however, varied their point of exit. In one of the covered bathing places, the supply of hot water had ceased and another spring became dry for 8 days after the earthquake.

Captain Banon stated that the very hot spring of Basisht in Kulu became quite cold after the earthquake while the lukewarm water of Kelat, four miles farther down the valley, increased its temperature. After a week or 10 days they resumed their normal condition. Thus it would seem that in some cases the effect of the earthquake may become permanent, while in others it may be temporary or transitory.

The springs at Mackinon's Brewery, Mussoorie, increased their discharge by about 20 to 30 per cent. after the Kangra earthquake. After the 20th May, 1905, the discharge began to decrease and by the end of June the flow was normal.

Conclusion :—In conclusion it may be observed that a very preliminary recording of the various kinds of springs has been so far made and there is undoubtedly a great scope for the detailed investigation of the waters of most of these springs. It is then only that we can assess correctly their value and exploit them for commercial comprising table, medicinal and other purposes. Even the present information about them is scattered very piecemeal in various publications, some of which may not be easily accessible.

CHAPTER XI

CLIMATE

In order to appreciate the nature of the climate of India, its position must be recalled. India lies both in the tropical and sub-tropical regions and the Tropic of Cancer passes through the Rann of Cutch, Dacca, etc., *i.e.*, almost through the middle of India.

It is remarkable that the sub-tropical zone, occupying Rajputana, Sind, Baluchistan and the Punjab, enjoys an extreme climate, while that of the tropical zone is appreciably more equable.

Seasons

In India generally the following are the three seasons which give the main phases of the climate of India :—

(*i*) Winter : November to March.
(*ii*) Summer : April to May or June.
(*iii*) Rainy season : June to October.

The duration of each season, however, may vary appreciably in different parts of the country.

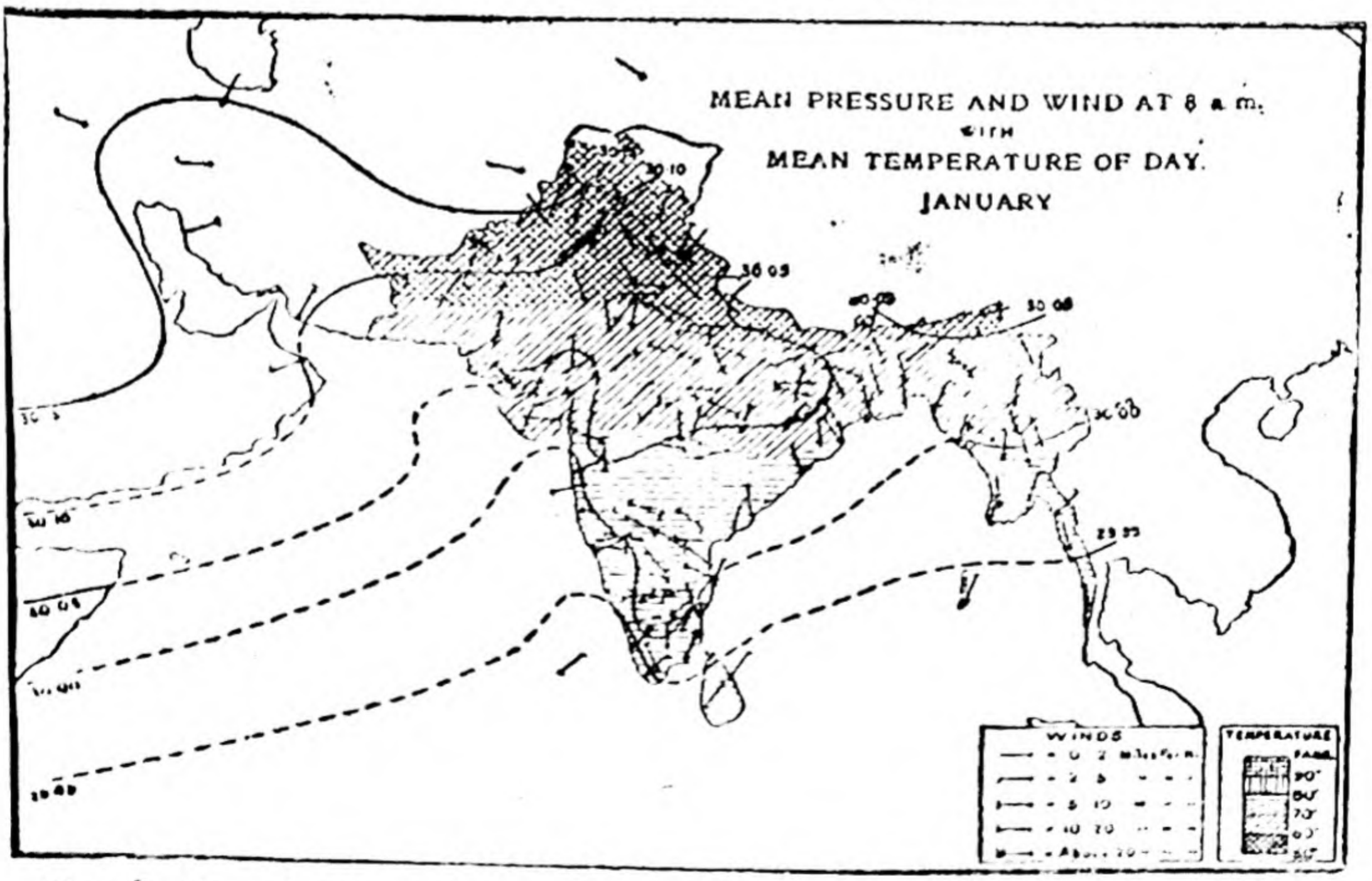


Fig. 7—Showing mean temperature, pressure and winds in January.

Winter Season :—During winter, of which typical months are December and January, the sun is shining vertically south of the equator. India, therefore, experiences low temperatures which gradually decrease towards the north (See Fig. 7). At this time, the temperature is the lowest in the north-west and in the Himalayan region, where mean temperatures of 50° to 60° prevail. This increases in the east as well as in the south, where mean temperatures of 70° to 80° are experienced. This is clear from the fact that the average January temperature for Madras is 80°, while the average temperature for Delhi for this time of the year is about 59°. The average January temperature for Lahore, which is situated in the plains of the Punjab, is about 54° or about 25° cooler than Madras.

Another factor, which affects the temperature, is altitude. The latitude of Lahore is slightly higher than that of Simla, which is situated about 7,000 feet above sea level, but the average temperature of the latter is about 14° lower than that of Lahore.

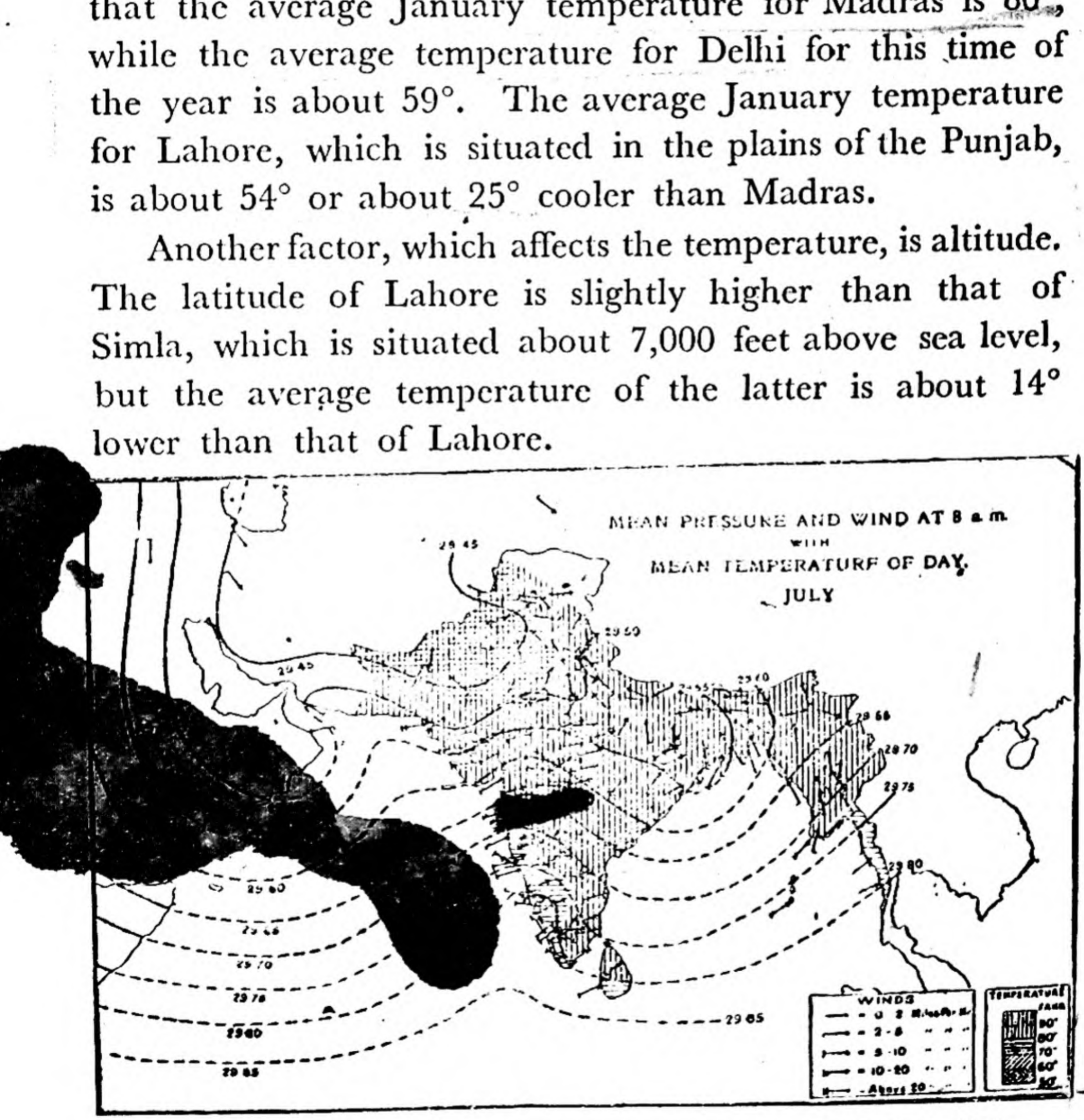


Fig. 8—Showing mean temperatures, pressure and winds in July.

Summer Season :—During summer the sun is shining vertically north of the equator, and India at this time of the year experiences very high temperatures which increase towards the north (See Fig. 8). North-West India, including Rajputana, Sind, Baluchistan and the Punjab, represents the hottest part with a mean temperature of 90°. The west coast, as it receives the full vigour of the south-west monsoon, enjoys a little lower temperature than the rest of the Peninsula. The effect of altitude is again marked. Places on the higher parts of the plateau of the Deccan, *e.g.*, Bangalore and Ootacamund, enjoy much lower temperatures than those on the east and west coasts. The hill stations of the Himalayas likewise experience much lower temperatures.

In the west and the south of the peninsula, April is the hottest month, while in Central India, the adjoining regions and the northern portion of the peninsula, May is the hottest month. In the north, *i.e.*, in the Punjab, Sind and the United Provinces, June is the hottest month. It will therefore be observed that the heat travels northward with the sun.

Annual Range of Temperature :—North-West India enjoys an extreme climate and in the Punjab, the N.-W.F.P. and Sind, as shown below, an annual range of 80° to 92° may be experienced. The annual range for the hill stations in the Himalayas is less as shown by the following figures :—

Murree	..	..	69°
Simla	..	..	63°
Darjeeling	..	..	47°

From the north the annual range of temperature decreases eastwards to Bengal and southwards to Travancore as will be clear from the undernoted figures :—

Lucknow (U.P.)	..	..	76°
Allahabad (U.P.)	..	..	76°

Patna (Bihar)	..	.. 68°
Calcutta (Bengal)	..	.. 54°
Silchar (Assam)	..	.. 54°
Cochin (Cochin State)	..	.. 20°

It may be noted that the annual range is greater in the interior of the peninsula than on the coast, and it is more on the east coast than on the west coast. The range actually depends on the winter cold than on the summer heat.

Pressure :—The pressure follows the temperature. In winter, when the temperature is the lowest in North-West India, it forms a region of high pressure, anti-cyclonic in character, and the land winds blow from this region. But in summer North-West India forms a region of low pressure and moisture-laden winds, called the south-west or the summer monsoon, as explained below, blow from the sea on to the land.

Rainfall

Monsoons :—India enjoys a monsoon climate and forms one of the monsoon lands of Asia. But it is to be observed that India has its independent centres of low and high pressure, which, along with its orography, determine the direction of winds. It enjoys the south-west monsoon, as explained below, from June to October when this direction is reversed and gradually becomes north-east. These south-west and north-east directions really hold good for the Bay of Bengal and the Arabian Sea, otherwise the actual local direction is determined by the orographical conditions.

South-West Monsoon :—When India is in the throes of the hot weather, the land gets very highly heated and naturally the air in contact with it also becomes very hot and rises up with the result that winds laden with

moisture blow from the Arabian Sea and the Bay of Bengal on to India. These winds usually blow from the south-west and are called the south-west monsoons. As stated above, these winds blow both from the Arabian Sea and the Bay of Bengal and thus there are two branches of the south-west monsoon, *viz.*, the Arabian Sea Branch and the Bay of Bengal Branch. (See Fig. 9)

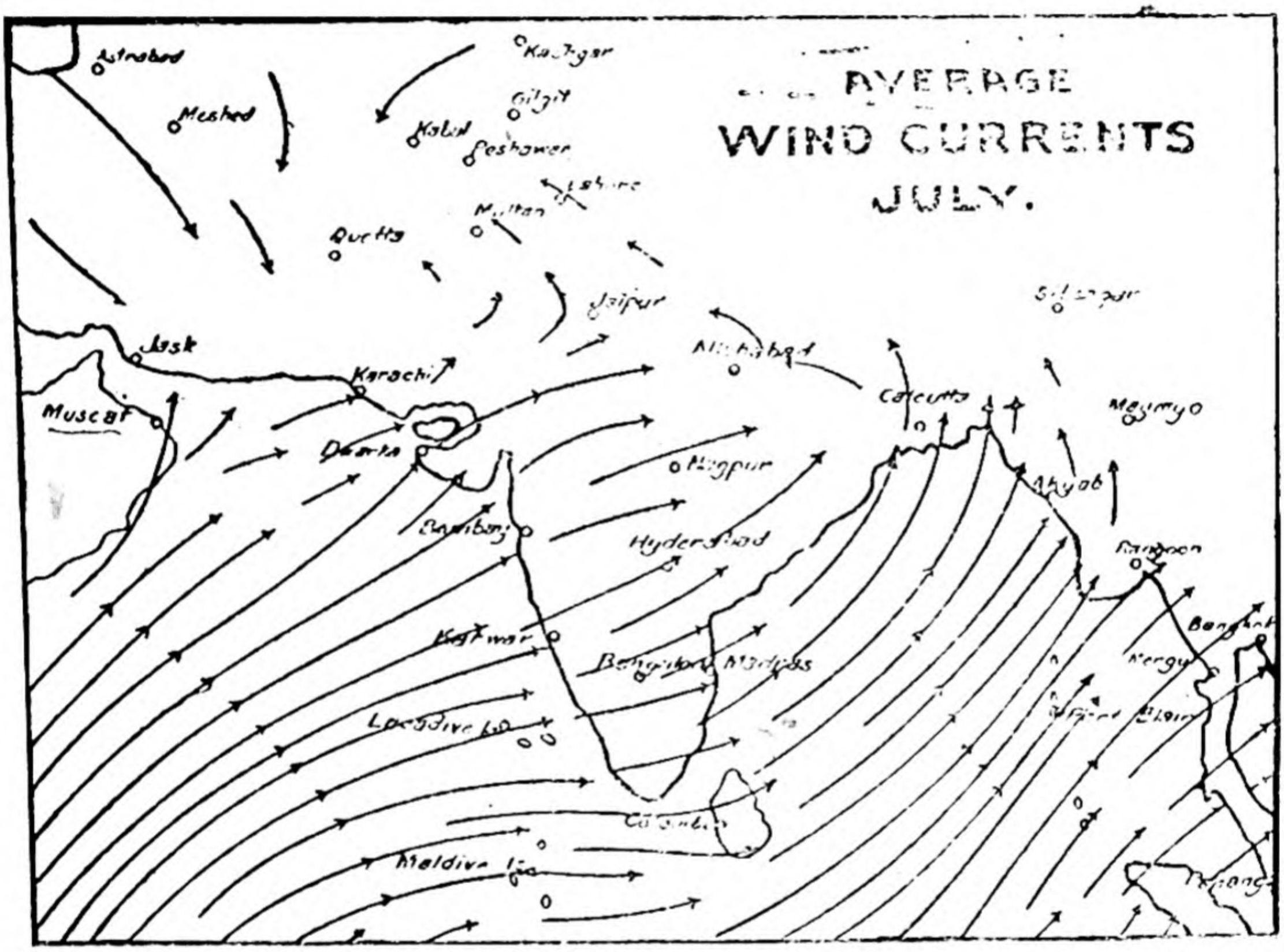


Fig. 9—Showing the South-West Monsoon Winds.

Arabian Sea Branch :—This branch strikes the Western Ghat with full vigour and a large quantity of the moisture is precipitated, and the coastal region and the Ghats receive a very heavy rainfall indeed. Towards the south of the peninsula, the direction of the winds is south-west, while in the north, it may be westerly, but after striking the Ghats, the direction on the Deccan plateau becomes westerly and which give rain in a smaller degree during June, July and August.

Bay of Bengal Branch :—This branch starts its career from the Bay of Bengal with a south-westerly direction and a part goes to Assam and the Eastern Himalaya. The province of Assam gets the full effect of these winds and receives a heavy rainfall, but owing to the configuration of the country the rainfall varies greatly within short distances. The average annual rainfall for Shillong is 82 inches, while Cherrapunji, which is hardly 30 miles away, is the wettest spot on the face of the earth and has an average rainfall of 458 inches *per annum*. The maximum recorded rainfall at this place was 905 inches in the year 1861 and of this 503 inches fell in two months, June and July. The rainfall at Goalpara and Lakhimpur is 115 inches, while at Sibsagar it is 85 inches, but at Nowgong it is below 43 inches. At Sylhet and Silchar the figures are 157 and 124 inches respectively. The average for the province of Assam is certainly excessive and, not infrequently, the rivers are flooded.

The winds have a southerly direction in Bengal and after striking the Himalayas they proceed up the valley of the Ganges as easterly winds. They give abundant rainfall to Bengal and to a lesser degree to Bihar and the United Provinces. The rainfall gradually diminishes as one proceeds to the west.

It may be noted that the summer monsoon winds are variable in the Punjab, the easterly winds dominate, which represent the branch blowing up the basin of the Ganges. The Arabian Sea current blows with a south-westerly direction from the coast of Gujarat, Cutch and Sind over Rajputana, where it almost passes over unchecked giving little rain. The two branches unite, at least partially, in the Northern Punjab. The south-west monsoon is not a persistent

wind. It undergoes changes in direction and strength, and often there are prolonged periods of calm when breaks or periods of interruption of rain occur, which alternate with showers of rain.

It may also be noted that there is a westerly wind, which blows over the peninsula as far north as the Satpura range, while, on the Gangetic plain, an easterly wind prevails. The region between these is a disputed one, where sometimes one current and sometime the other dominates; the westerly current is, however, stronger of the two.

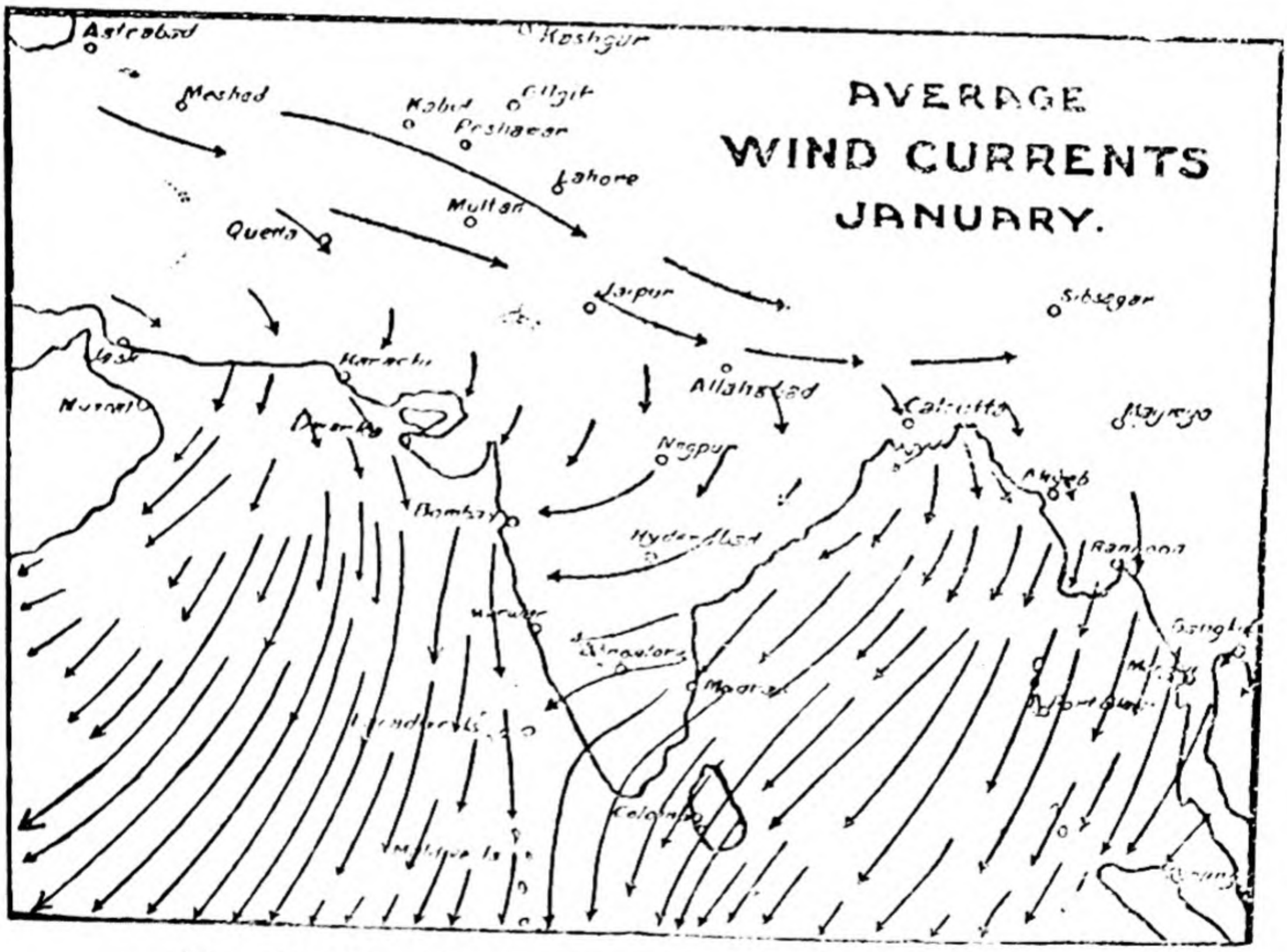


Fig. 10—Showing the North-East Monsoon Winds.

North-East Monsoon :—In September the strength of the south-west monsoons begins to diminish and the centre of low pressure moves towards the south, until, towards the close

This chapter must be carefully read — Pyare Lal Saxena 18 1954 (Hindi)

of October and in the month of November, it is over the Bay opposite the east coast. At this time of the year the winds become north-east (See Fig. 10), which, being land winds, are as a rule dry, but these winds, while passing over the Bay of Bengal, collect some moisture, which on striking the land give some rain to the Carnatic coast of India in November, December and January. Thus, this part of India receives rain twice a year both from the south-west and north-east monsoons.

The seasonal rainfall of India is shown in Figs. 11—14. From these figures it will be observed that, for a large part of India, most of the rain falls during the south-west monsoon season, *i.e.*, from June to September.

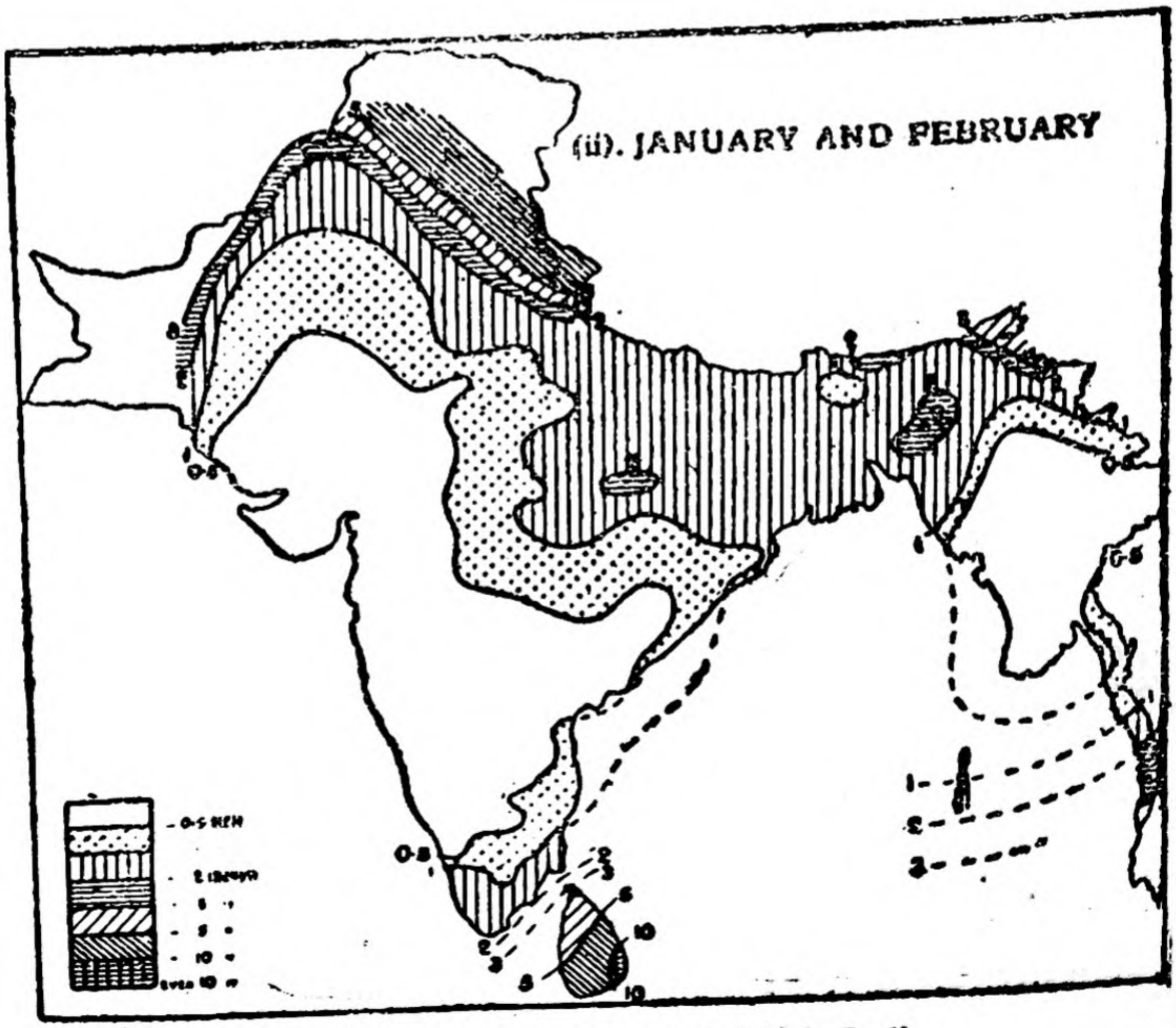


Fig. 11—Showing winter rainfall in India.

The rainfall during winter is very small but it is of great economic importance for the production of wheat and other grain crops of a great part of Northern India. The rainfall for Peshawar from December to March is 5.75 inches, while the total amount during June to September is 4.76 inches. This shows that the winter rain is certainly greater than that of the summer monsoon.

The Carnatic coast receives rainfall from the north-east monsoon mainly during November and December. It may be noted that the rainfall for Madras from June to September amounts to 15.46 inches, while that from October to December is 31.78 inches, showing thereby that winter rain is about twice that of the summer monsoon.

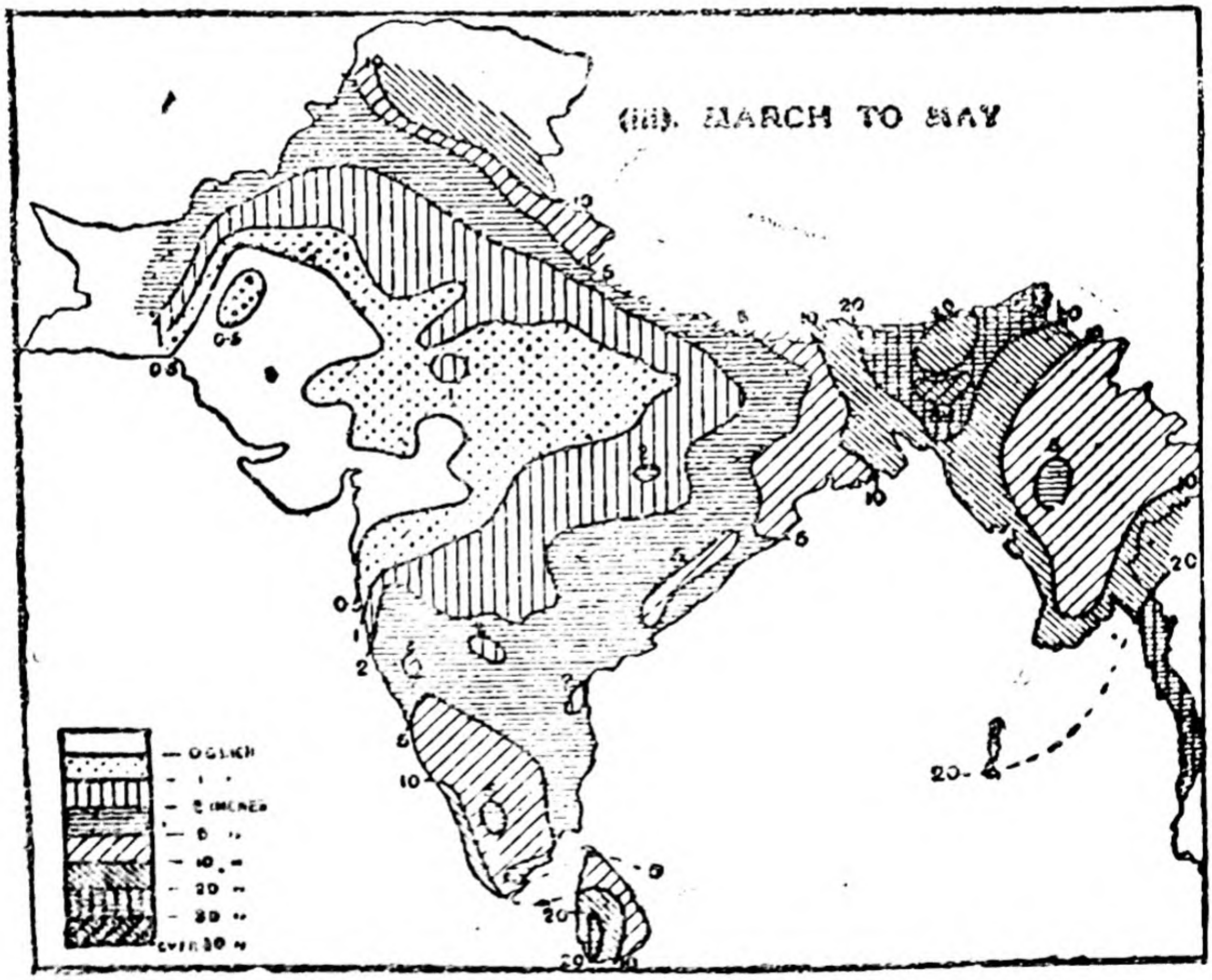


Fig. 12—Showing rainfall from March to May in India.

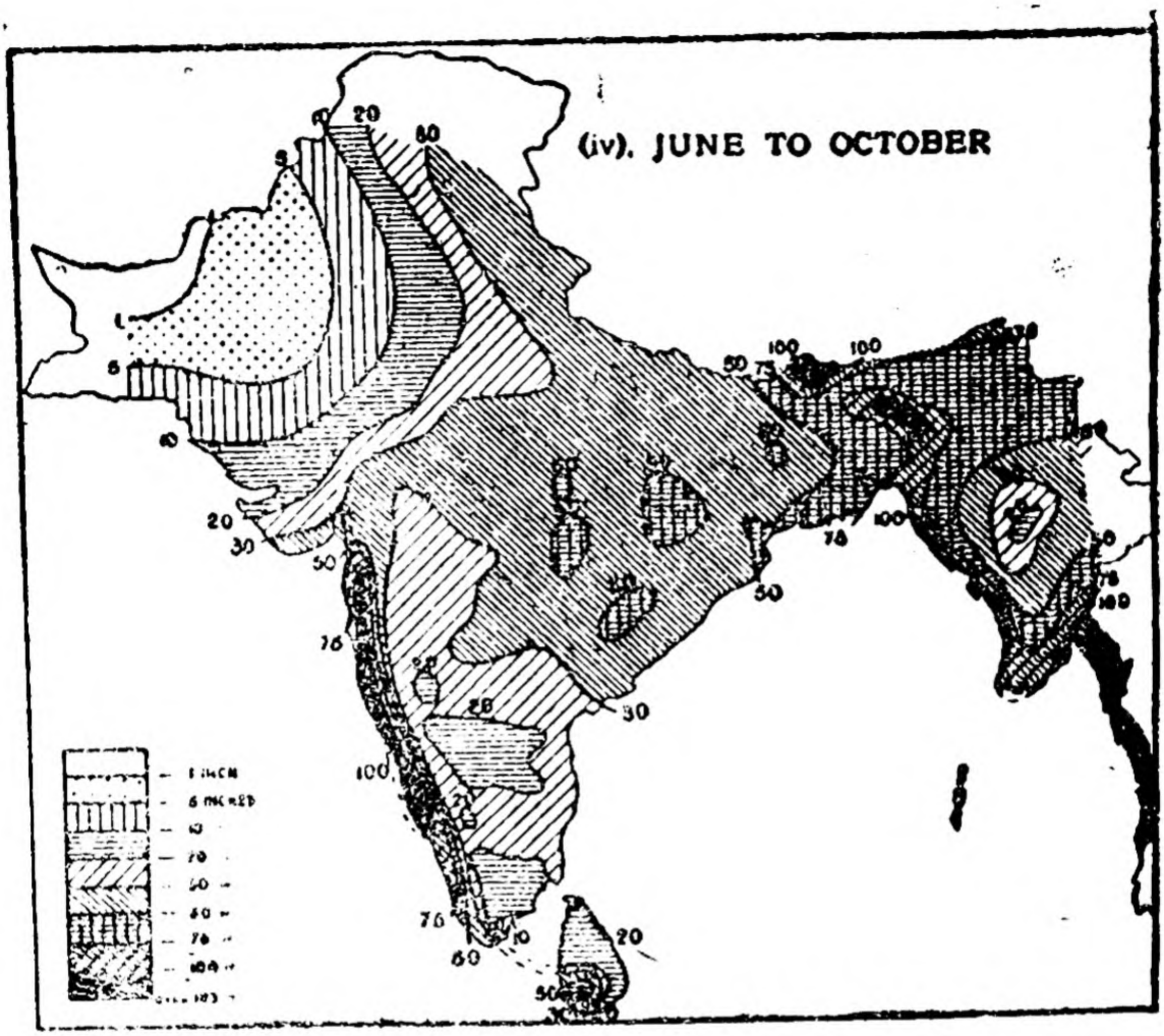


Fig. 13 —Showing rainfall during South-West Monsoon.

The map showing average annual rainfall (See Fig. 15) reveals that the west coast and the southern edge of the Garo and Khasi hills and the Eastern Himalaya receive the heaviest rainfall, which may exceed 100 inches *per annum*. On the other hand, the area which receives the minimum rainfall of less than 10 inches per year is the Thar desert along with the adjoining parts of Sind, Baluchistan and the Southern Punjab. The remaining part of India receives rainfall between 20 to 80 inches *per annum*. The areas adjoining the coast and the Himalayas receive higher rainfall than those situated in the interior.

Important Features of Rainfall in India

1. It is noteworthy that the distribution of the rainfall in India is determined mainly by the orography of the country.

2. The advent of the south-west monsoon may be delayed considerably, which will affect the *kharif* sowing.

3. The south-west monsoon may commence much earlier, with the consequence that it may also terminate much earlier. This will damage the *kharif* crops and also make the sowing of the winter or the *rabi* crops difficult or uncertain.

4. Prolonged breaks of rain may occur during July and August, when the standing crops need rain the most.

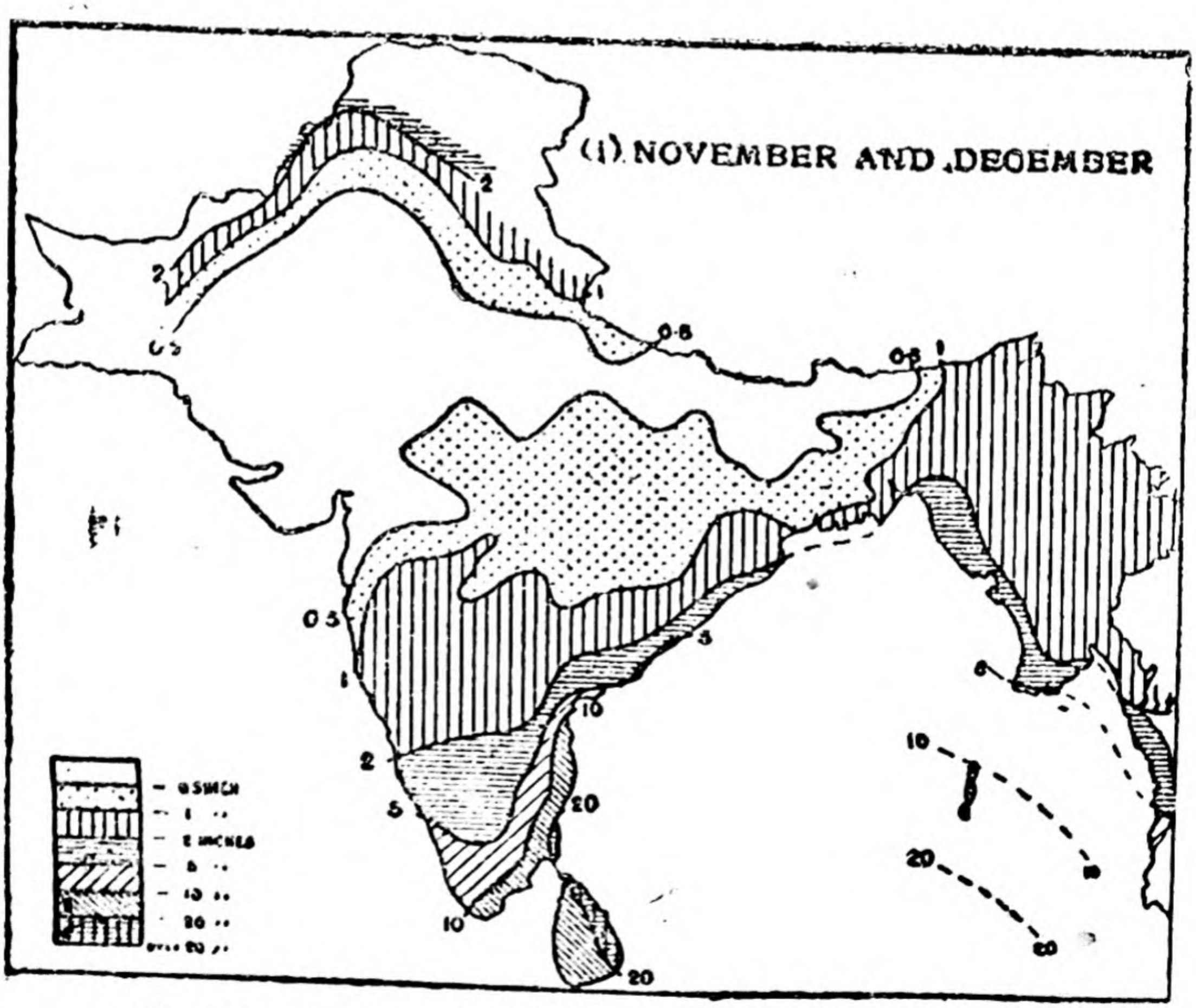
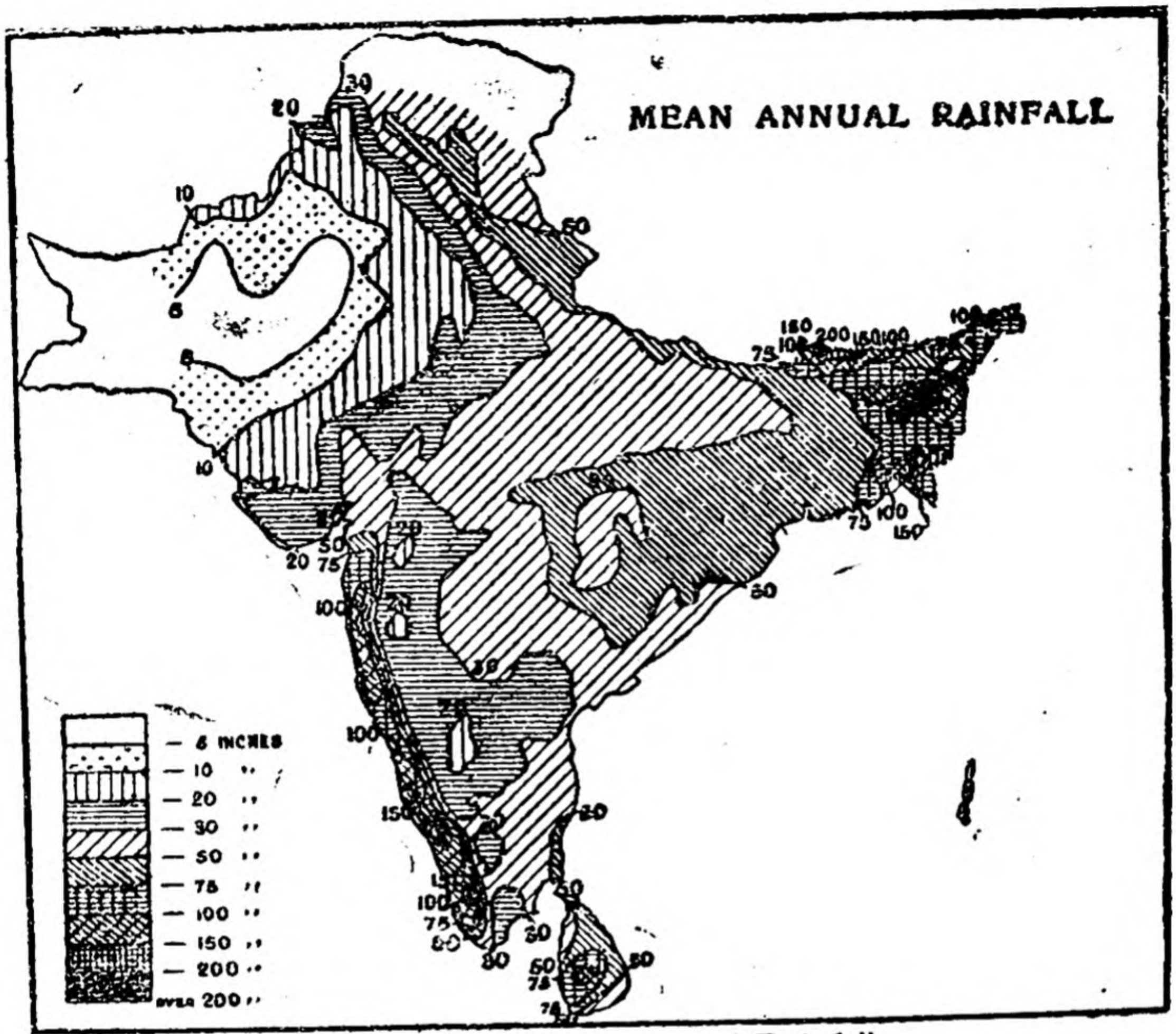


Fig. 14—Showing rainfall during North-East Monsoon.



Mean Annual Rainfall.

Fig. 15—Showing mean annual rainfall of India.

5. The rain from the summer or the south-west monsoon generally falls in torrential downpours, with the result that a very great part of it is wasted as run-off without giving proportionate benefit to the soil.

In the past, the failure of the monsoons used to result in great famines. Their failures were of little consequence either in areas of heavy or scanty rainfall, but were disastrous in areas with 30 to 50 inches of rainfall. But today these famines cannot be so severe owing to the construction of irrigation works, the railways and famine relief works.

Cyclonic Storms :—The Indian seas are at times visited by cyclonic storms which are generally oval or

circular in shape. The air moves in converging spirals in a left-handed anti-clockwise direction. Towards the centre, the winds are very fierce and almost have the fury of a hurricane. Generally, these cyclones die soon after they reach the land, but they sometimes cause great damage in coastal districts as a result of terrific winds, torrential rainfall and mountainous sea waves. The latter are the most destructive, particularly in the low-lying districts, where the moving mountain wall of water may flood the country and sweep anything that comes in its way. Thus sometimes these storms are responsible for great loss of life. These storms are experienced either before or with the advent of the south-west monsoon, *i.e.*, in May, or at the end, in October and November.

Do not be misled. Please read only selected chapters from this book

CHAPTER XII

CLIMATIC REGIONS OF INDIA

India, being a sub-continent with its high mountains, enjoys all variations of climate. For instance, the climate of Assam in the east is extremely damp and stands in great contrast to that of Sind in the west, where the climate is essentially very dry. Similarly, the climate of the Punjab, which enjoys an extreme climate and has a bracing winter for about seven months, is absolutely different from that of Travancore in the south, which enjoys an equable hot, wet equatorial climate. Below are, therefore, described some of the important climatic regions, beginning with the Himalayas in the north.

The Himalayas:—The altitude of the Himalayas from the outer hills to the highest peaks is quite sufficient to experience all varieties of climate from the tropical heat to the alpine or the polar climate. These changes of climate are remarkably displayed in the vegetation of the area. At 7,000 feet, which is about the average altitude of the Himalayan hill stations, Darjeeling, Naini Tal, Mussoorie, Simla, etc., the mean winter temperature is 44°, while the mean summer temperature is 65°. In the valleys, however, a temperature of 90° to 100° may be experienced during the day in summer. At an altitude of 9,000 feet the mean winter temperature is 32°, while at 12,000 feet the temperature is above freezing point during summer from the end of May to the middle of October, but at 15,000 feet it is never above the freezing point even in mid-summer. It may be noted that the climatic conditions of Tibet differ greatly from those of the Himalayas. The climate of Tibet is very dry and the daily range of temperature may be as much as 50° to 60°.

Rainfall :—The Himalayas intercept the moisture-laden monsoon winds, and thus experience a rainfall similar to the plains of India; only they may receive larger rainfall with a longer rainy season. It is noteworthy that the eastern part of the Himalayas receives much larger rainfall than their western counterpart. The Himalayas may, therefore, be sub-divided into two regions, *viz.*, the Eastern and the Western Himalayas. In the east the rainfall may be as much as 50 to 80 inches *per annum*, on the southern hill-slopes while in certain places this total is considerably exceeded. The rainfall decreases gradually towards the west; it is 40 inches at Hardwar where the Ganges leaves the Himalayas, while it is 30 inches where the Indus leaves the mountains. In places which are in rain-shadow, it may not exceed 15 inches.

Snowfall :—In the Himalayas, the precipitation is both in the form of rainfall as well as in that of snowfall. In the eastern region, the normal winter limit of snowfall is about 6,000 feet above sea level. In the Kumaun Himalayas it is about 5,000 feet and is occasionally even as low as 2,500 feet above sea level. It is remarkable that snowfall has been recorded at Peshawar.

North-West India :—North-West India, comprising the provinces of the N.W.F.P., the Punjab, Sind, Baluchistan and perhaps also Rajputana, represents one unit so far as the climate is concerned. The climate of the whole of the region is extreme in character, with very cold winters and very hot summers. It also forms a very dry region, in fact the driest region of India. A great part of this region comprising almost the whole of Rajputana, Sind, Baluchistan and a great part of the Southern Punjab is a desert, not because the soil is barren, but only because of the scantiness of rainfall. Wherever, water for purposes

of irrigation is available, the soil has yielded very good crops.

It may also be observed that some parts of this region, *e.g.*, the N.W.F.P. and the Northern Punjab, receive cyclonic rain during the cold season from January to April, and sometimes these showers bring more rain to the area than the south-west monsoon. These winter rains are useful to wheat and barley crops of this region. This area really forms a separate climatic region with well-marked winter rains.

It has been noted above that the main region shows the greatest annual variation of temperature. The mean maximum temperature in summer at Lahore is about 117°, while the mean minimum temperature is only a few degrees above the freezing point. The figures for Delhi, as compared to those of Lahore, show a small variation of a few degrees.

Sind is the hottest and also the driest province of India. The river Indus flows through the province; only recently several canals have been taken out of this river by building the Sukkur Barrage, and there is no doubt that these irrigation canals have added materially to the prosperity of this province. But where the benefits of irrigation are not available, it is mainly a sandy or a stony waste. Jacobabad is the hottest place in India, while Karachi, being close to the sea, enjoys a more moderate climate.

Rajputana, which again enjoys a small precarious rainfall, is considered to be a transitional zone between Sind and the plateau of Central India. The region is generally described as a desert, but it may be noted that it is inhabited and, wherever possible, cultivation is also carried on with the help of deep wells. It is

covered with a dry scrub type of vegetation. In places the tract is covered with sand-dunes which are constantly shifting. To the east of the Aravallis, the rainfall exceeds 20 inches. The winter rainfall throughout Rajputana is considerably lighter and less regular than in the Punjab.

The Gangetic Valley :—This region, represented by the basin of the river Ganges and its tributaries, covers mainly the United Provinces and Bihar and enjoys a climate intermediate between Bengal on the east and the Punjab on the west. It enjoys in normal years a rainfall from 30 to 50 inches, but in parts of the Ganges-Jumna *doab*, it is below 30 inches *per annum*. It may be observed that the *doab* has been subjected to some of the worst famines. Consequently, after the famine of 1834, the construction of the Upper Ganges Canal, one of the greatest irrigation works in the world, was undertaken. In April, May and part of June, until the rains break, a very hot scorching wind blows, which starts a few hours before midday and stops sometime in the evening or at nightfall. At times, it continues even through the early part of the night. The hottest days of the region almost rival those of the Punjab, but sometime in June, generally about the middle, dust storms set in, which tend to lower the temperature and are generally followed by rain. With the advent of rains, the dry hot wind disappears and there is a lowering of the temperature. But when the rains are interrupted by dry breaks, the weather may become very sultry and close indeed. The rains cease sometime in September, and in October light winds begin to blow from the west and the cool season sets in. The weather remains fair until about Christmas, but in January and February there may be a few showers. Winter rain in the Gangetic valley is much lighter and more irregular than in the Punjab.

It is noteworthy that this region, along with the provinces of Bihar and Bengal, constitutes the most fertile, and intensely cultivated region of India. It is also the most densely populated part of India. There is no part of the plains, which is unsuited to agriculture, save where by the development of *reh* or saline salts, the tract has been converted into *usar* land. The sub-montane tract is occupied by the Sal forest, while the plains, which are above the flood level of the rivers, are called the *bhangar*. Here only dry farming can be carried on, except where canal or well water is available for irrigation. The land adjoining the rivers and subject to their inundation is called *khaddar* and here, in places, the cultivation of rice can be carried on. As in the North-West, the *Kharif* or summer crops comprise rice, oil-seeds, sugar-cane, cotton, millets, etc., while the *rabi* or winter crops include wheat, barley, grain and pulses.

Assam and Bengal :—This region enjoys very damp climate. The rainy season is much longer and the rainfall much heavier. A part of Bengal is formed of the deltas of the Ganges and the Brahmaputra along with the plains in the north. In the delta area there are numerous waterways and swamps which, of course, along with the heavy rainfall, keep the humidity high, which manifests itself in fogs in the valleys and congested parts of towns.

The cool season is much shorter, which lasts from sometime in November to the latter part of February, and the winter rains are only occasional. The hot season sets in with March, and during this month and April, the highest temperatures are experienced. Some thunder squalls along with dust storms are also experienced. In May or early part of June, cyclones may visit Bengal but they

are more to be expected towards the end of the monsoon. With the beginning of June the monsoon sets in. It continues through July and August and ceases sometime in September, when the breaks between the showers become more frequent and the temperature rises. This period, until the cool season sets in, is very oppressive and unhealthy.

It may be observed that the economic products of Bengal are determined by its climate. Rice is the most important crop and forms the staple food of the people. Two crops of rice are cultivated, *i.e.*, the *Aus* and the *Amun*. Pulses and oil-seeds are also grown. In Northern Bengal, jute and tobacco are extensively grown, and this region, along with some of the adjoining areas, is believed to form a monopoly for the jute crop in the world. Other products of this region include hemp, cocoanuts, sugar-cane, mulberry for rearing silk worms, betel leaves, bananas, etc.

Towards the east, Assam enjoys a still higher rainfall and a damper climate with the result that vegetation grows very profusely. In Assam, the largest area in India, about 40 per cent. is under forests. Here tea plant is indigenous and cultivation of tea is carried on on a very extensive scale.

This region enjoys moderately high and sometimes equable temperature and a high humidity at all seasons, being protected from the westerly desiccating winds. In the cool season fogs are very frequent, particularly in the valleys and low ground. On the southern side of the Garo and Khasi hills, the rainfall is very heavy and torrential. The Assam Range, including the plateau of Shillong, thus forms a separate climatic region. The rainfall in Assam begins much earlier and continues until

October. The country enjoys a great natural scenery in its hills, rivers and the forests which abound with wild game, including rhinoceros and bison. Tea and rice are the important products of the region, but the latter is hardly adequate for local consumption. Other minor products comprise India rubber, oranges and betel-nut.

Western Coast :—The western coast of India along with the adjoining portion of the hilly country is certainly a definite climatic unit. It enjoys heavy rainfall during the south-west monsoon and the region is covered with evergreen vegetation. The region extends over 13 degrees of latitude, *i.e.*, from 21° to 8° North latitude. It enjoys, however, a uniform climate with a mean annual temperature of 79° or 80°. The rainfall on the Western Ghats is much greater than on the coastal region, as shown by the figures given below :—

The Western Ghats.		*The Coastal Strip.*	
Mahableshwar..	255 inches.	Mangalore ..	119 inches.
Matheran ..	244 inches.	Ratnagiri ..	100 inches.
		Bombay ..	73 inches.
		Surat ...	42 inches.

Under these conditions the vegetation is prolific and the undergrowth is so thick that it gives an impression, particularly in the south, of the vegetation of the equatorial zone. Thus the States of Travancore and Cochin form another Climatic sub-region. Cardamoms, pepper and cassia abound in the jungle, and these represent products for export.

Plateau of the Deccan :—The interior of the peninsula enjoys a very different climate from the west coast. Within a short distance from the top of the Western Ghats

enjoying a torrential rainfall and evergreen vegetation, is reached the plateau of the Deccan which enjoys a scanty and somewhat precarious rainfall. In this region to the south and south-east of Bellary, there is a tract which receives under 20 inches of rainfall and has consequently suffered from some of the worst famines. This tract is covered with coarse grass or a scrub jungle. The teak is restricted to the zone adjoining the Ghats, where the rainfall exceeds 30 inches, while in Mysore grows the sandalwood (*Santalum album*), the most valuable tree in the south.

The Carnatic Region—This region, as noted above, receives rainfall from both the monsoons and thus it differs from other parts of India in several respects. In this region the following four seasons are experienced:—

(1) Hot season from March to the end of May.

(2) South-West monsoon rainy season from June to the beginning of October.

(3) North-East monsoon rainy season from early October to the middle of December.

(4) Cool season from the end of December to the end of February.

Thus it will be noticed that there are two well-marked rainy seasons experienced in this region. The dry season begins with the middle of December, and almost continues to the latter part of June. In April and May there is some rain, which is known as "Mango Showers", as mangoes begin to ripen at that time. They are known as "Blossom Showers" in the coffee-growing region. The rainfall from the south-west monsoon, *i.e.*, from June to October is somewhat light, but in the interior it is considerably more scanty.

The north-east monsoon gives the coastal region a somewhat heavier rainfall. It is accompanied sometimes by severe cyclonic storms, which cause considerable devastation on the coastal regions, particularly when they are accompanied by huge storm waves, which sometimes rise to as much as a moving wall of 20 feet of water. Several such storms have caused terrible havoc at different times to the coastal towns of Masulipatam, Madras, Vizagapatam, Coconada, etc. In this region the cool season is not at all well-marked. The climate of this region is aptly described as "nine months hot and three months hotter." During March and April the hot land winds prevail in the interior which in places sweep down to the coastal region. The "long shore" winds, which are damp, enervating and very disagreeable, blow from the south along the coast of Madras at this time of the year. The land wind blows from the cooled land to the warm sea in the morning, while the true sea-breeze blows from the east in the evening. On the whole the climate of this region is dry, particularly in the interior; but on the coast the rainfall is above 40 inches *per annum*.

In this connection it may be noted that the Palghat gap in the Western Ghats, having a width of about 25 miles, has an important influence on the climate of the Central Carnatic region on the one hand and the coast of Malabar on the other. It affords a clear passage to the easterly and westerly monsoons. Through this gap the effect of the south-west monsoon from the Arabian Sea is felt as far as the east coast, and is responsible for moderating the heat of the Tanjore district. Except in the delta regions, where anicuts and canals have been constructed, irrigation is carried out by means of tanks, some of which are a few miles in diameter. Rice, which forms the staple food of the people, is the principal crop along with millets, etc.

CHAPTER XIII

WEATHERING AND DENUDATION

Denudation is the term applied to the general wearing away of the rocks by natural agencies, the most important being the sun, wind, rain, running water, frost, moving ice or glaciers, sea and, to a smaller extent, plants and animals. The action of these agents is also responsible for the decay and disintegration of rocks and thus play a very important rôle in soil formation and soil erosion. The importance of their study cannot be over-emphasised in a country like India. By the transportation and deposition of the eroded material, new land is gained in deltaic regions. By the erosion of rocks and subsequent deposition, detrital mineral deposits like those of gold, tin, manganese, monazite, ilmenite, etc., are formed, both on the river and sea beaches. A brief account of how, in different parts of the country, the various agents of denudation work, is given below.

India is situated in the tropical and sub-tropical regions and enjoys a monsoon climate. It experiences, as discussed in the preceding Chapters, a wet season lasting from June to October followed by a dry season. The most important agents of weathering are rain and running water, assisted very strongly by insolation or heat of the sun. In the desertic regions the action of wind is very dominant. It may be noted, however, that the greatest amount of denudation or lowering of the surface of the country is brought about by the action of rivers.

India, being a vast sub-continent, falls into a number of climatic regions, which have been discussed in Chapter XII. In different regions the action of different agents

of destruction predcminates. For instance, conditions of weathering and denudation are absolutely different in Assam and the Eastern Himalaya from those in Sind, Rajputana, Baluchistan, etc.

Insolation or Changes of Temperature :—The action of the sun is very strong all over India, particularly during the hot season in North-West India, comprising Sind, Baluchistan, the Punjab, Rajputana, etc. In these regions difference between day and night temperatures is great, sometimes as much as 80°. During the day, when the temperature is very high, the mineral particles, of which the rocks are composed, expand. During the night, when the temperature falls, they undergo contraction. Different minerals have different cc-efficients of expansion and contraction. As a result of repeated unequal expansion and contraction of minerals for a long time, the rock crumbles to powder forming an expanse of sand or desert as in Rajputana, etc.

Action of Wind :—Wind is air in motion and it always blows from a region of high pressure to that of low pressure. The velocity of the wind depends upon the difference in pressure; the greater the difference, the greater the velocity of the wind. In the Himalayas wind sometimes blows with such a terrific velocity that it is able to break "needles", knife edges and thin crests of rocks. In a storm, the uprooting and breaking of trees, telegraph and telephone posts is a commonly observed phenomenon.

The action of wind is particularly strong in the desert of Rajputana and the adjoining regions. The rock powder or sand, produced by the changes of temperature, is taken up by wind and transported for large distances. It is noteworthy that wind, as also the ice, is capable of trans-

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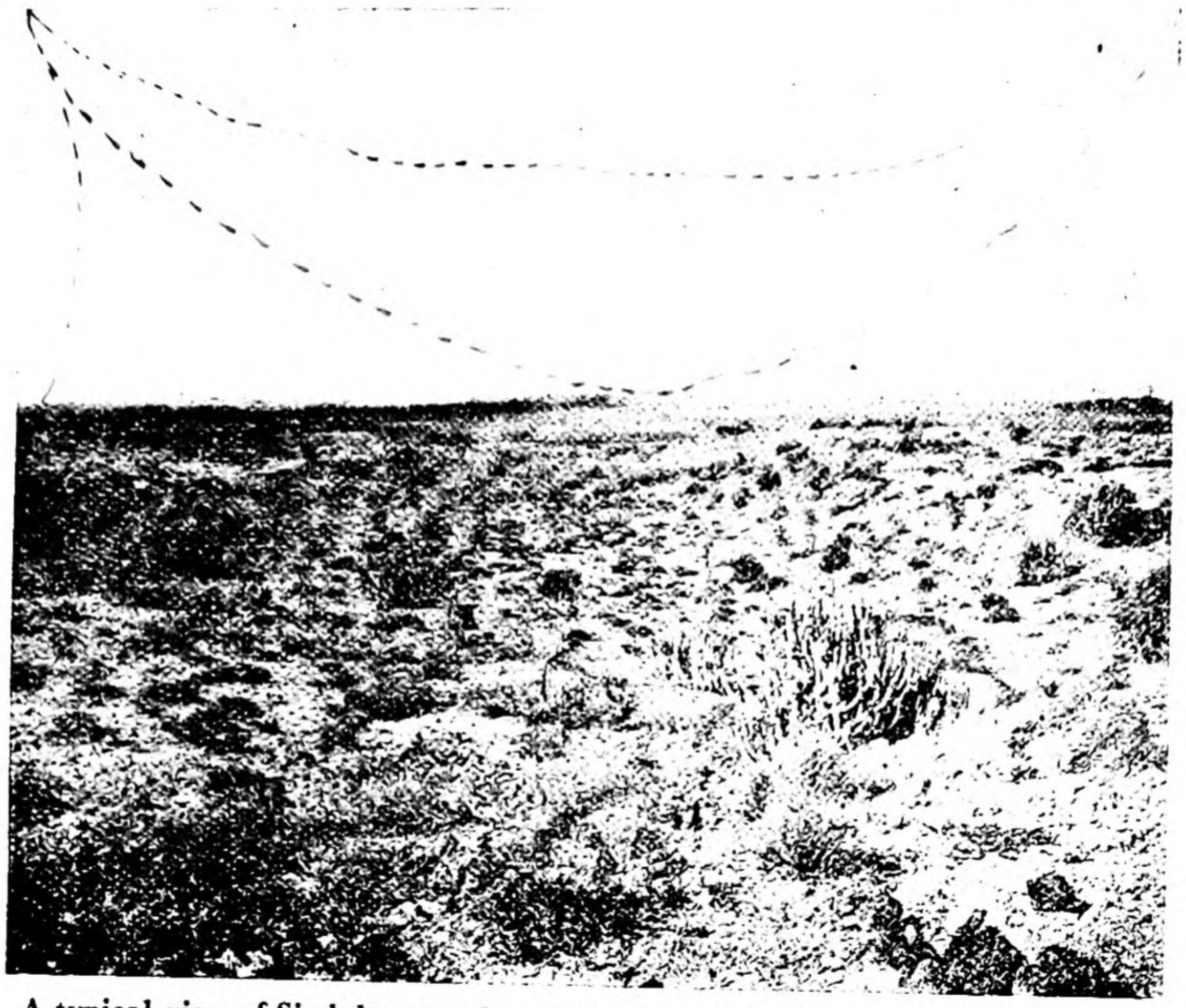
Plate VIII



A typical view of Sind desert, where the action of the Sun and wind are the dominant agents of denudation. (*By the courtesy of the Bombay Natural History Society*)

porting material uphill against the action of gravity. Fine dust may be carried for hundreds of miles. Volcanic dust from the eruptions of Krakatoa in 1883 was transported for nearly 2,000 miles, and even caused sunset in Europe. Dust storms before the advent of rains are common in Northern India.

Sand-Dunes :—The sand of the desert is picked up by wind and carried for some distance until the velocity is arrested and the rock material is deposited in the form of a sand-hill called a sand-dune. It has a gentle slope on the windward side and a steep slope on the leeward side. This sand may be taken up again and deposited in another position. These shifting sand-dunes are very vividly seen in Rajputana, the Southern Punjab, etc. Sometimes cultivation fields may be buried below these sand-hills.

Polishing and Undercutting of Rocks :—Wind, when loaded with particles of sand, acts as a natural blast of sand. It polishes, cuts and carves the rock against which the wind blows. Such polished rock surfaces are to be seen in the arid regions of Rajputana, etc. As most of the material blows only a few feet above the surface, the rocks are undercut and may form tables, mushrooms or other fantastic shapes. Furthermore, the softer rocks are denuded, while the harder portions are left standing conspicuously. Sand particles by mutual attrition become finer.

Action of Rain :—Rain acts in two ways: mechanically and chemically. In the wetter parts of India torrential showers of rain simply by their impact wash away all loose detritus to the nearest stream. The streams, which are ordinarily clear in the dry season, become muddy during the rains, *e.g.*, the Ganges, the Jumna,

the Indus, etc. The mechanical effect of rain is the greatest on steep slopes, because the gravity also plays its part. On cliffs and precipitous hill sides no soil is to be observed, as it is removed as soon as it is formed. But in the valleys and plains it accumulates to great depths.

A heavy shower of rain is capable of removing far greater quantity of loose material than the same amount spread over a number of gentle showers. In the Eastern Himalayas, where the maximum rainfall is about 500 inches, and that too practically in four months, the extent of erosion by rain and running water is simply enormous.

When the land is not covered with vegetation and the rocks are soft, even in arid regions, they are easily eroded away, converting the area into a 'badland' topography (See Plate X, Fig. 1). This is observed in many parts of India and is described in some detail in Chapter XVIII.

Earth Pillars :—Sometimes there is an admixture of boulders in soft material. The soft material from the area is easily eroded away while the resistant boulder forms a protective capping. Thus a pillar is formed which is called an earth pillar. They are commonly seen in the Salt Range, etc.

Protective covering of Vegetation :—The importance of the protective covering of vegetation and thus forming a check on erosion has been discussed in Chapter XVIII.

Chemical Action of Rain :—Pure water is not a good solvent, but rain water, while passing through the atmosphere, absorbs carbonic acid gas. Its solubility is then considerably augmented, particularly on a rock like limestone, which is well-bedded and jointed. The water, charged with carbon dioxide, begins to act along these joint and bedding planes and removes the limestone rock in solution. Thus large hollows, caves and caverns are formed.

In these caves, stalactites and stalagmites are formed. Some of the water from the roof, before dripping on to the floor, is evaporated and leaves a deposit of carbonate of lime until an icicle or a pillar hanging from the roof, and called stalactite, is formed. Some of the water with carbonate of lime in solution drops to the floor. It evaporates there leaving behind a deposit, until a pillar called stalagmite, rises from the ground. These pillars have fantastic shapes and sometimes stalagmites and stalactites join together and add greatly to the beauty of the chambers in which they occur. Such caves with stalactites and stalagmites are to be observed in limestone and dolomite districts of India. One such notable and easily accessible locality is that of Sahasradhara in the Dehra Dun district. Here caves with fantastic deposits are to be seen and it forms a well-known tourist and picnic resort.

Calcareous tufa is deposited particularly in the courses of streams. These deposits have a banded, concentric growth and are sometimes burnt for lime.

Likewise, rocks like gypsum and rock salt, for example, of the Salt Range, are removed in solution. Thus the Salt Range presents some peculiar features in its denudation. There is, of course, surface denudation by rain, running water and wind, but denudation by solution takes place from within also. By torrential rain, rock salt, gypsum and dolomite are removed in solution, thus creating large underground hollows which cause the subsidence of the upper portion. In the year 1925 a great subsidence occurred, which engulfed half of the important village of Khewra.—In fact subsidences are taking place in the region occupied by the Saline series almost every day. Keeping the pucca drains, built in sandstone or

limestone intact is a great problem for the Salt Department. Almost every day portions of these drains settle down, thus dislocating the whole drainage and causing no small inconvenience to the Department concerned.

Landslips are also quite frequent in the Salt Range, particularly where the rocks are composed of the soft, friable material, for example, the Saline series. As a result of torrential rains aided by gravity, the rocks sometimes undergo a series of landslips, as was particularly observed in the neighbourhood of Warchha Salt Mine.

The Salt Range also furnishes excellent examples of denudation of limestone regions in a somewhat arid climate. Large areas are occupied by the Permo-Carboniferous and Nummulitic limestones. The strata are usually well-bedded and jointed and show the usual limestone topography with flat plateau-like dip slopes on one side, and very steep escarpments on the other, which form almost wall-like inaccessible masses. Sometimes a waterfall may appear on an escarpment slope. Usually the rock is bare, with little soil, as the limestone happens to be pure.

The gorges in this limestone have been referred to above, but considering the size and the depth of the gorges it appears that the present streams, which remain practically dry over the greater part of the year, appear to have been incapable of having carved such deep chasms. Of course these streams suddenly become torrents during the rains. The author, along with Professor Sahni and a party of students, had a surprising experience of a sudden rain in October in the Warchha gorge. The stream, which was very tiny, almost a trickle during the day, became highly swollen with waves after a small rainfall late in the evening when the party was just emerging, somewhat

opportunely, out of the gorge. To new visitors to the Salt Range, a word of caution may be sounded—that it would not be wise to be in the gorge during rain. The country being largely composed of limestone, there is no percolation into the rock with the result that all the rainfall collects and rushes as a torrent on a sloping bed of the gorge.

But it is very likely that these gorges were carved out during the late Tertiary or Pleistocene times when the climate was cooler and more moist than at present.

Formation of Kaolin :—Rocks, *e.g.*, granite, basalt, gneiss, etc., rich in felspars, which are silicates of potassium, sodium, and aluminium, are easily decomposed both by agents of weathering and by superheated waters. Potassium and some of the silica are removed in solution leaving behind a compound containing alumina and some silica with the addition of some water. This hydrated compound is kaolin or china clay. In India this clay is derived from various kinds of rocks. For instance, it occurs associated in several places with granitic gneiss of the Ranchi district, Bihar and occurs associated with bauxite deposits representing an ore of aluminium.

These clays are also of residual origin. For example, they may be formed from limestone. Carbonate of lime is removed in solution, while the small proportion of the associated clay goes on accumulating, with the result that ultimately a large deposit of clay is formed. The clays, which are associated with the Vindhyan limestones in the neighourhood of Katni, are probably of this origin.

Formation of Laterite :—The alternation of wet and dry climate in India helps to produce a peculiar rock

called laterite. It is soft when freshly cut, but hardens on exposure to air. In India laterite is known to originate from various kinds of rocks, for example, basalt, granite, gneisses, periodotites and serpentines, etc. It has been observed to be also associated with clays, shales, sandstones, etc. During the rainy season the water soaks into the altered rock along with compounds of iron, etc. During the dry season these solutions are sucked up by capillarity and are deposited in the upper portion. By the deposition of ferruginous material, it is coloured yellowish-red or dark brown with a peculiar vesicular or cellular structure. On an exposed surface it forms a hard crust, which might ring under the feet. It is used for building purposes and also serves as an inferior type of road metal. Some of the aboriginals in the Chota Nagpur plateau, still use it as an ore of iron.

Action of Running Water:—Rivers of Northern India are perennial as they are fed during the dry season by springs and by the melting snow and ice, while those of Southern India generally run dry. But all Indian rivers are in flood soon after the advent of rains and they bring about tremendously greater erosion in one season than they could have normally accomplished in a number of years, had their volume remained practically constant. This is due to the fact that a river in flood has great velocity and thus its transporting power is considerably augmented. A river, particularly in spate, transports rock-material (*i*) in suspension, (*ii*) in solution and (*iii*) by rolling along the bottom. The rivers of Northern India, *viz.*, the Indus, the Ganges and the Brahmaputra are some of the fastest eroding streams of the world. It has been estimated that the Indus transports to the sea, on an average, about a million tons of silt per day, while the Ganges carries 0·9 million tons and the Brahmaputra

a little more than the Indus. In the hilly regions a river performs erosion, while in the plains the main work is transportation. In the delta regions the material is deposited. Southern India is a peneplain and the rivers, as noted above, have reached their base level of erosion and thus cannot bring about any vertical erosion. They can only affect lateral erosion. But in floods their work is also comparable to those of the Himalayan rivers. During the rainy season, the volume of these rivers is also considerably increased and owing to the transportation of material they become very muddy. The author remembers a very vivid experience. He happened to cross the Tungabhadra river during the rainy season when it was swollen and, no doubt, appeared to be a big rushing river. But when he crossed it again in the following March, he could not believe his own eyes; there was no river and only the dry bed was to be seen.

In the moist regions of the Eastern Himalayas, the valleys become broad and V-shaped as in this case rain tends to wear away the sides of the valley. But if the climate is arid, for example, in the Salt Range, then the streams carve out U-shaped valleys or gorges. It is only the sawing action of the running water which is responsible for carving out the gorge; the action of rain on the sides is practically absent. There are many gorges in the Salt Range, *viz.*, the Khewra, Makrach, Warchha, etc.

Formation of River Deltas :—When the rivers reach the sea, their velocity is suddenly checked by encountering the sea water. Thus the river is relieved of its load. The sea water is saline and some of the load is also precipitated. By the deposition of the load, across its channel the river bifurcates repeatedly until a triangular piece of land, called the delta, is formed. The deposits in the delta

regions are often thick, particularly of big rivers like the Ganges. The alluvial deposits near Calcutta are more than 500 feet thick. The Sunderbans of the Ganges provide a very clear example of a river delta. Most of the important rivers of Southern India have deltas at their mouths and they form fertile lands, which, when irrigated, make very productive areas.

River Bars :—A bar or a spit may be deposited at the mouth of a tidal river as a result of the alternating movement of the sea and river water. The Hooghly, for instance, is a tidal river and a number of bars occur in its lower course. Thus the ships have to be navigated very carefully by pilots. For instance, a vessel coming from Rangoon to Calcutta will halt at the mouth of the Hooghly to pick up a pilot of Calcutta Port Trust, who will bring it carefully to Calcutta. Sometimes, if the water is low, a ship may have to wait until high tide to proceed further.

Action of Frost :—The action of frost is very severe in the Himalayan region. Water soaks into the pores and crevices of rocks. The temperature at night is so low that it congeals. The water on freezing expands in volume by about one-tenth, and thus exerts a great pressure within the rock or on its sides. During the day the ice thaws and the pressure is released. By this repeated process the rocks are broken along joint cracks, etc., and fall to pieces. Thus on a hill-slope, blocks are dislodged forming the scree or talus material which is very commonly observed in the Himalayas, for example, at Simla, Kashmir, etc. The presence of scree material makes climbing very difficult.

This process is even repeated in the wedging of the mineral grains. Thus the rock ultimately crumbles

into small pieces. Rain and running water then act upon these and they undergo further erosion. Landslips and landslides, as a result of the work of these agents, are very common in the Himalayas and often breach the railway, road and telegraph communications.

Work of Glaciers:—The significance of snow-line and its altitude in the various parts of the Himalayas have been stated above. In cold regions the precipitation is largely in the form of snow which accumulates at the head of the valleys. Owing to pressure, the lower portions are converted into ice, which is forced to escape lower down. Thus originate the gigantic glaciers of the Himalayas which have been treated in an earlier chapter. The movement of a glacier is comparable to that of a river. It is faster in the middle and is slower on the sides and at the bottom. When a glacier is moving on an uneven surface it develops large cracks, through which the surface moraines reach the bottom.

The work of a glacier is similar to that of a river and comprises erosion, transportation and deposition. The glacier, which moves slowly, tends to scour the bed of the valley, which is rendered smooth, polished and scratched. A glaciated valley is always U-shaped as the action of rain on the sides is absent. It transports blocks of rock which may be carried in various positions on the surface, or along the bottom, when they will also become smooth, scratched and faceted.

Where the glacier terminates, because ice melts more quickly than it is replenished, the moraine material, which was being transported by the glacier, is deposited and is called terminal moraine, found in various parts of the Himalayas. One of the easily accessible localities is near Gulmarg in the Pir Panjal Range in

Kashmir. These terminal moraines may be covered with grass and form pastures for nomadic tribes, for example, Bhoteas, in summer.

Sometimes a tributary glacier valley may terminate higher than the main valley. Such valleys are called hanging valleys and are commonly to be seen in many parts of the Himalayas. These hanging valleys afford a definite testimony of ice erosion.

Work of Sea :—India, as stated in the foregoing, has a long coast-line. The work of the sea is done by its movements which comprise waves, tides, and ocean currents. Waves in a stormy weather during the monsoon may be very high and strong and they, by their impact and constant hammering, batter down the coast and may detach fragments of rock. They may be taken up by waves, and are rolled to and fro, until they are reduced to shingle and gravel, and may ultimately be pulverised to sand which is deposited on the beach, for example, the beaches of Bombay and Madras. The breakers are assisted in their work by the contraction and expansion of the air in the joints cracks of the rocks.

Aggrading Action of the Sea :—The aggradational action of the sea may not be omitted. It is noteworthy that on land destructive processes dominate, while in the sea the aggradational or constructive work is more important. These processes may be classified as follows :—

(*a*) By mechanical movements of water detrital material is deposited. The detrital deposits of monazite and ilmenite have been thus laid on the coast of Travancore.

(*b*) By chemical precipitation limestone and iron ores are deposited.

(*c*) Some deposits, like coral limestone, shelly limestones and carbonaceous material may be laid by organic agencies. Sometimes a large block of rock may be composed entirely of a colony of corals. The Laccadive islands are coral islands built on submerged rocks.

Action of Organic Material:—Organic material comprises both vegetable as well as animal matter. These have destructive as well as constructive action.

Destructive Action of Vegetable Matter:—Trees split even hard rocks asunder by forcing their roots into tiny cracks or crevices. They thus open up the subsoil to the action of atmospheric agents. By the decay of plants, humus acids are formed which act chemically on rocks and minerals.

The constructive action of vegetable matter lies in its accumulation and its ultimate conversion to peat, lignite, bituminous coal and anthracite. Coal may be formed either *in situ*, *i.e.*, where the trees originally grew or the material be transported for some distance and then deposited.

Action of animals:—Earthworms, which are so common in wet parts of India, bring the soil in a very finely divided state to the surface, which will be easily carried by rain water. White ants also act likewise. Burrowing animals like rabbits, etc., also bring soil to the surface, which being in a loose condition, will be easily removed by rain or running water.

Considering the action of the various agents of denudation, India can be divided into a number of belts or zones. Commencing from the north the Himalayas will have to be sub-divided into a number of regions: (1) the Eastern and Central Himalayas where the action of rain and run-

ning water is predominant. (2) In the Western Himalayas, however, the conditions are much drier. Then the Himalayas will have to be classified into a number of belts depending upon altitude above sea level: (*a*) the outer foot-hill zone where rain and running water are mostly responsible for denudation, (*b*) the Middle Himalayan zone where the action of frost and glaciers predominates and (*c*) the Great Himalayan zone, where a great part is covered under snow and ice. Here owing to extensive cold there is no decomposition of rocks and minerals, but only their disintegration takes place. (3) The next area is the N.W. desert, where insolation and the action of wind are the predominant agents of denudation. (4) The Western Ghats where the rainfall ranges from 80—200 inches per year. Of course the action of rain is dominant and most of the torrential streams drain into the Arabian Sea. (5) Farther south occurs almost the equatorial region with a good rainfall and luxuriant vegetation. Here chemical decomposition to a great depth represents the most important phase of weathering. The formation of clay and laterite are the salient features. (6) The plateau of the Deccan receives less rainfall and here, by the action of rain and as a result of the alternating dry and wet season, abundant laterite is formed. (7) In the Deccan the Nilgiri hills must form a separate region with high altitude and higher rainfall. In winter there may be frost action but in summer rain and running water try to erode these hills.

Peneplain and Cycles of Erosion :—The final result of the action of all the agents of denudation is to lower the surface of India. They are particularly trying to lower the elevation of the Himalayas and of the plateau of the Deccan. Of course the Himalayan rivers are immature but in the latter case the base level of erosion, as noted

already, has been attained. When such a stage is reached, it is said to have become a peneplain. But there are cycles of erosion. Once a country has become a peneplain, earthquakes, volcanoes, secular changes of upheaval and subsidence tend to disturb this equilibrium and the agents of denudation, once again, begin their task of erosion.

CHAPTER XIV

GEOLOGY

It would be helpful to give a brief account of the geology of India, as it plays an important part in the economic and industrial development of India. First, the different minerals are associated with the rocks of the different periods. Secondly, the geology and the overlying soils have an important effect on the natural vegetation. Likewise, the cultivated crops are also dependent upon the soils; hence the *regur* is also called the Black Cotton soil of India as it is particularly suited to the cultivation of cotton.

The author observed an almost classical example of the control of natural vegetation by the underlying geology. Whilst investigating the serpentine rocks of the Henzada and Bassein districts, Lower Burma, with which chrome-iron ore was associated, it was noted that in the northern portion *In* (*Dipterocarpus tuberculatus*) along with long grass was the sole vegetation on these serpentine deposits. But this was replaced by the bamboo *Myinwa* (*Dendrocalamus strictus*) in the south. With the help of this knowledge, the writer could locate the serpentine deposits much more easily than it would otherwise have been possible while working in an almost impenetrable jungle. I may usefully add another remarkable example of the association of the specialised type of vegetation with the lavas of Mount Popa region in the Myingyan district, Burma. It was noticed that the different kinds of lavas supported special type of flora. For instance, the trees growing on the rhyolite (acid lava) and rhyolite tuffs of the Kyaukpadaung hills were entirely different from those of the andesites and basalts (intermediate and basic lavas) of the main

mass of Mt. Popa. The same facts were observed while investigating the Girnar hills in Kathiawar. The Deccan Trap with the overlying Black Cotton Soil or *Regur* has also its own specialised type of vegetation. Sal (*Shorea robusta*) does not grow on the Deccan Trap and is replaced by teak (*Tectona grandis*) which is somewhat stunted. Instances could be added but the above will go to prove that not infrequently the underlying geology and soils have a definite effect on the nature of vegetation. Similarly, the mineral wealth associated with the Archaean rocks is entirely different from that associated with the Vindhyan or the Gondawana or the Tertiary strata of India. It is, therefore, imperative to be at least familiar with the rudiments of the geology of India.

In order to understand the geology of India, its geological record preserved in its rocks has to be studied. This record has been divided into five main groups, which are separated from one another by gaps or breaks in the record of succession of events, or by changes in the character of the animal or plant life on the earth's crust. It is mainly with the help of the remains of animals or plants preserved in these rocks that it has been possible to study the different chapters of this record. In brief, the remains of ancient animals and plants, called fossils, help geologists in deciphering the history of the earth in much the same way as coins or other relics of former times help an archaeologist.

The main rock-groups of this geological record in order (the oldest first) are:—

(1) Archaean, comprising the most ancient crystalline rocks, large parts of which were consolidated from molten matter and may, in part, represent the primeval crust of the earth. Some other parts may be derived by

their disintegration and subsequent deposition. These rocks have been greatly altered and no traces of life are found in them.

(2) Palaeozoic or Primary, in which early or ancient life is found. This represents the longest era in the history of the earth.

(3) Mesozoic or Secondary in which organic remains are intermediate in character between those of the Palaeozoic and modern times.

(4) Kainozoic or Tertiary, the animal and plants remains of which begin to resemble those of the present day.

(5) Quarternary and Recent. This represents the present era in which we are living.

The last four rock-groups were mainly deposited in the sea and some of the rocks have marine shells entombed in them. The thickness of the strata of these groups also gives some idea as to the approximate duration of each period. For purposes of detailed study these rock-groups are further sub-divided into systems, systems into series, series into stages, etc. But for our present purposes familiarity with the names of rock-groups and systems, which are tabulated below, will be sufficient.

(5) Quarternary and Recent	..	Recent and Sub Recent Pleistocene.
(4) Kainozoic or Tertiary, (later stages of the earth's history),	..	Pliocene Miocene Oligocene Eocene.

(3) Mesozoic or Secondary, (middle ages).	..	Cretaceous Jurassic Triassic.
(2) Palaeozoic or Primary, (early ages of the earth's history).	..	Permian Carboniferous Devonian Silurian Ordovician Cambrian.
(1) Archaean or Pre-Cambrian.		

It may be noted, however, that the breaks in India did not coincide with those of Europe and America. Between the Archaean and the Palaeozoic rocks of India are some transition rocks which have been styled as the Purana group and comprise the Cuddapah and the Vindhyan systems. The Palaeozoic group up to the end of the Upper Carboniferous is called the Dravidian group. Above this group there is a universal, well-marked break and all the succeeding formations are grouped under the name Aryan.

Archaean Rocks

These oldest rocks in India, which consist of gneisses and schists, occupy a considerable area of the Peninsular region. The Archaeans of India have been divided into :—

B. Dharwar System.

A. Archaean System.

The Archaeans proper consist mainly of gneisses which have been classified into—

(*a*) the Bengal gneiss,

(*b*) the Bundelkhand gneiss,

(*c*) the Nilgiri gneiss.

This last-named gneiss comprises the well-known Charnockites, the hypersthene-bearing rocks which range in variety from the granites, syenites, gabbros to ultra basic representatives.

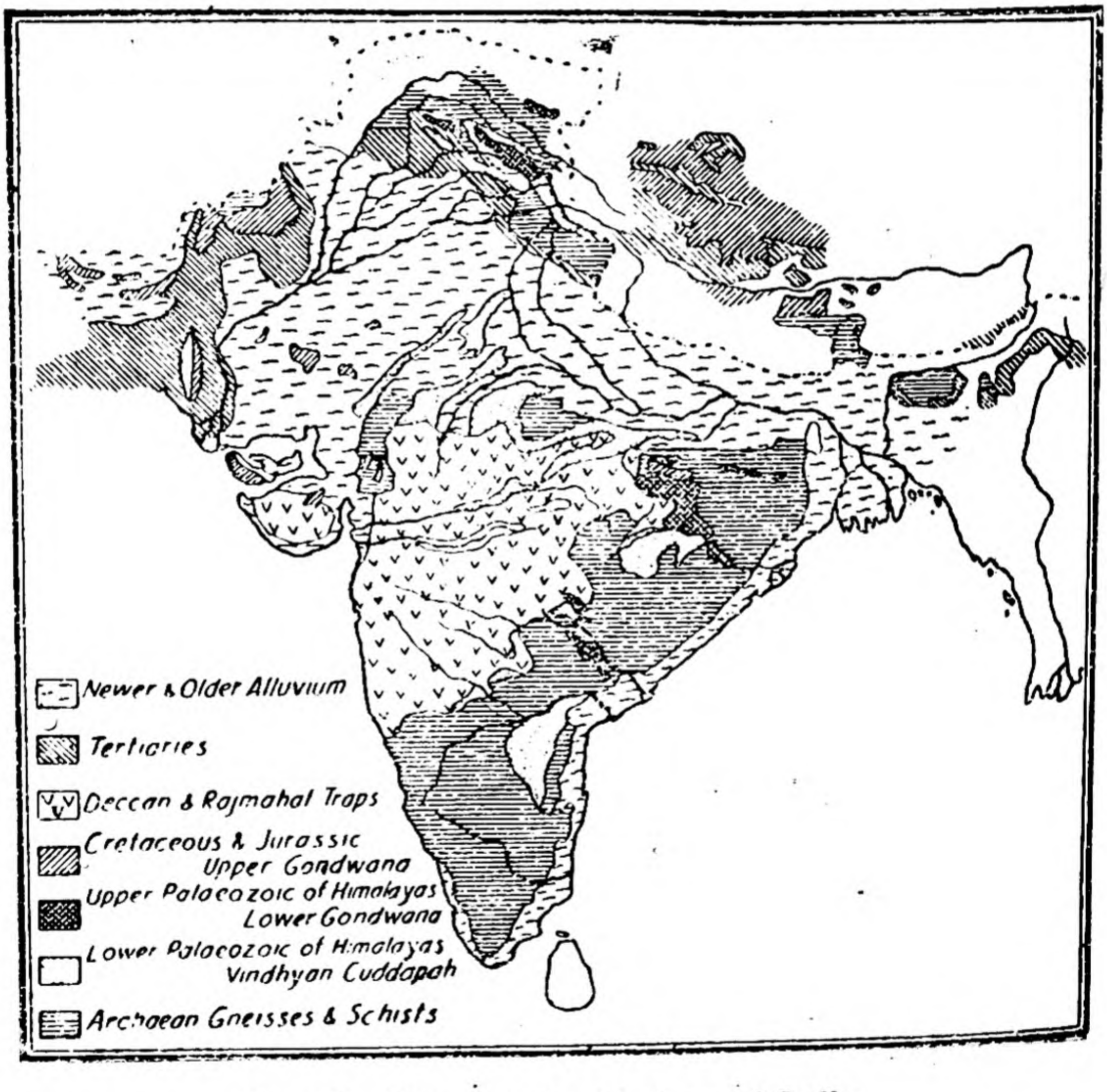


Fig. 16.—Showing the Geology of India.

The Dharwars consist of quartz-haematite-schists, quartzites, hornblendic, micaceous and chloritic schists, jaspers, etc. Manganese and iron ores occur associated with them. These rocks are chiefly of sedimentary origin which have undergone great metamorphic stresses. They

occur in narrow elongated synclines resting on the gneiss found in the typical Dharwar region including the Bellary district, the State of Mysore, the Central Provinces and the Aravallis of Rajputana.

Economically, these Dharwar rocks are very important as they are gold-bearing, *e.g.*, Kolar gold-field in Mysore, manganese in Central India and iron in the State of Mysore and the district of Salem in the Madras Presidency.

The Khondalites, and the Gondite series, which are manganese-bearing metamorphosed sediments, found in the Balaghat, Chhindwara, and Nagpur districts of Central Provinces are believed to be of Dharwar age.

In the Extra Peninsular region, these rocks are not well-developed but the Vaikrita system consisting of the schists, phyllites and gneisses and occurring in Hundes, Kumaon and Spiti area, are recognised to be the Himalayan representatives of the Dharwars. Similarly, the Daling series in Sikkim and the Shillong series in Assam, composed of the schists with interbedded trap, are also believed to be of the same age.

At the end of the Archaean Era, severe diastrophic movements occurred with the result that these rocks show evidence of having undergone great dynamic stresses. They have undergone great folding, dislocation and metamorphism, with the development of acute foliation, cleavage, etc. It was at this time that these rocks were upheaved from the bed of the sea and have, as stated above, never been submerged beneath the sea with the exception of a few marine transgressions near the coastal regions. The mighty chisel of nature, in the form of the various agents of denudation, has been actively busy, ever since, in the wear and tear of these rocks.

The Purana Era

The Purana rocks comprise the Cuddapah and the Vindhyans. The former are divided into :—

B. The Upper Cuddapah.

A. The Lower Cuddapah.

The Cuddapah system is developed on the eastern side of the Madras Presidency and occupies an area of roughly 14,000 square miles. Lithologically, these rocks comprise quartzites, sandstones, shales and slates with associated limestone, conglomerates and igneous rocks. The last named comprise numerous intrusions of basic igneous rocks as also interbedded lava flows and ash beds.

Vindhyan System

The Vindhyan rocks occur in some of the eastern districts of the United Provinces and also in Central India, south of the Jumna and the Ganges and north of the Narbada and the Son and cover an area of more than 40,000 square miles.

It is to be noted that the sandstones are the predominant rocks with subordinate interbedded shales and the former, being considerably more resistant, form a series of well-marked scarps so well observed in these ranges. The total thickness is about 14,000 feet and the rocks are either almost horizontal or dip at very low angles.

The Vindhyan rocks have been classified into :

B. Upper Vindhyans,

A. Lower Vindhyans.

The Upper Vindhyans are composed of sandstones, shales, limestones and conglomerates with two distinct diamondiferous horizons.

Cambrian

From now onward we deal with the fossiliferous sediments of India. The earliest rocks belong to the Cambrian period and they are well-developed in (*a*) the Salt Range of the Punjab and (*b*) the Spiti area in the Central Himalayas.

The Salt Range:—In the Salt Range, the following sequence, in descending order, is observed:—

Salt Pseudomorph Zone:—It consists of flaggy dolomites and sandstones with pseudomorphs of salt crystals. It has a thickness of about 450 feet.

Magnesian Sandstone:—These rocks, which almost approach dolomites, contain only a few fossils and have a thickness of 250 feet.

Neobolus Shales:—These are composed of dark shales containing typical Cambrian fossils, *e.g.*, *Neobolus*, *Redlichia* and attain a thickness of about 100 feet.

Purple Sandstone:—The series comprises red or purple-coloured sandstones which are unfossiliferous and have a thickness of 250-450 feet. These rocks show current bedding, ripple-marks, sun-cracks, rainprints and worm burrows.

This sequence of the Cambrian strata is best seen in the Eastern Salt Range near Khewra both in the Khewra gorge as well as in the hill crowned by the Khusak fortress.

Saline Series:—The underlying group consists of Red Marl with beds of gypsum, rock-salt and dolomite. This series is of great economic importance because large deposits of rock-salt are associated with it. The age of these deposits is a very controversial question in the geology of

India and it has been aptly styled the "Panipat of India." Some geologists like Dr. C. S. Fox consider it to belong to Cambrian age, while others attribute a very late age (Tertiary) to these rocks. From the occurrence of the salt near Bahadur Khel in the Kohat district, which is found in the Tertiary deposits (Eocene), the present position of the Cis-Indus salt deposits is ascribed to an overthrust.

Spiti :—The Cambrian deposits of Spiti have been christened as the Haimanta system, which is composed of unfossiliferous slates, micaceous quartzite with interbedded fossiliferous dolomitic limestones containing fossils of Lower, Middle and Upper Cambrian age.

Ordovician

In Spiti, the Ordovician rocks exhibit the following sequence :—

(*iv*) Flaggy shales and limestones with typical Ordovician fossils with a thickness of 500 feet.

(*iii*) Red quartzites with a total thickness of about 1,500 feet.

(*ii*) Quartzites and sandstones.

(*i*) Conglomerates.

Silurian

Spiti :—In this locality of Spiti the Ordovician rocks are succeeded by siliceous limestones with corals and the typical crinoid, *Pentamerus oblongus*.

Muth Quartzite :—The siliceous limestones are overlaid by a white unfossiliferous quartzite, several hundred feet in thickness and occupying a large area. It is known by the name of Muth Quartzite. Its age is, however, uncertain ; it may be Upper Silurian or Devonian.

Kashmir :—In the district of Vihi in Kashmir, the Silurian are represented by fossiliferous beds, only about a

100 feet in thickness, which yield typical Silurian fauna. These are again overlaid by the Muth Quartzite, entirely unfossiliferous and with a thickness of 3,000 feet. It has been observed that *Pinus longifolia*, although growing elsewhere too, shows a peculiar preference for this siliceous and not very nutritious rock.

Devonian

Central Himalayas :—In this area the Devonian is represented by the Muth Quartzite overlaid by hard siliceous limestone. In the grey limestone, typical Devonian fossils along with corals, are found.

Chitral :—In the Chitral area the black limestone contains the Devonian coral and brachiopod fossils.

Carboniferous

Central Himalayas :—The Devonian limestones pass into the Carboniferous represented as follows :—

(*b*) Po Series—Upper Carboniferous.

(*a*) Lipak Series —Lower Carboniferous.

The Lipak Series is composed mainly of calcareous and sandy rocks with numerous species of brachiopods and some of trilobites.

The Lipak Series is overlaid by the Po Series which are composed of quartzites and dark shales, the uppermost layers containing the genus *Fenestella* and comprise the well-known Fenestalla shales of Upper Carboniferous age.

Kashmir :—In this area the equivalents of the Lipak Series of Spiti are known by the name of Syringothyris limestone with *Syringothyris cuspidata, Productus, Chonetes, and Phillipsia.* This limestone is succeeded by the Fenestella beds with *Fenestalla* along with some typical brachiopods. The Fenestella beds are overlaid by quartzites with intercalated shales with a thickness of 2,000 feet.

The Carboniferous strata are unconformably overlaid by a volcanic series comprising Agglomeratic slates, tuffs and a great thickness of andesites and basalts, etc. known as the Panjal trap. The Agglomeratic slates are also believed to be volcanic in origin. The slates are grey in colour and are composed of fine angular fragments of quartz, felspar, slate, quartzites, etc. The age of the volcanic series ranges from Upper Carboniferous to Trias.

CHAPTER XV

GEOLOGY—(*Contd.*)

Permian and Triassic

Towards the end of the Middle Carboniferous the Extra Peninsular region was upheaved, which was subjected to agencies of denudation. It was again invaded by the sea, well-known as the Tethys, which stretched from the Mediterranean in the west on to Burma in the east. The highest peaks of the Himalayas formed the southern shoreline of this ocean as the main beds belonging to the Aryan Era occur to the north. It may be noted that the great Continent of Gondwanaland lay to the south of this ocean. In the Himalayan area unbroken sedimentation occurred from the Permian to the end of the Cretaceous depositing a pile of strata, 7,000 feet in thickness.

Salt Range :—The Salt Range since the Cambrian period also remained a land-mass which was subjected to the action of the agents of denudation, but by the late Carboniferous movements it was also included in the zone of sedimentation, which continued with a few slight interruptions up to the close of the early Tertiary (Eocene). In this region occurs a Boulder bed of glacial origin, which is proved by the polished, faceted and striated nature of the boulders. This Boulder bed has an immense geological extent and indicates that the whole of the Southern Hemisphere was affected by a glacial period during the upper carboniferous times. The Boulder bed is overlaid by the Speckled Sandstone Series.

The Speckled Sandstone is succeeded by the Productus Limestone as various species of the brachiopod, genus

Productus, are prolific in this limestone. It is of marine origin with a thickness of 800 feet and is classified as follows :—

(*c*) The Upper Productus forms the Chideru stage and contains ammonites of Triassic age.

(*b*) The Middle Productus represents the Virgal stage.

(*a*) The Lower Productus forms the Amb stage and is equivalent of the Carboniferous Fusulina limestone of Europe.

Ceratite Beds :—These beds are of Triassic age and have been named after the caphalopod genus *ceratite*. They consist of arenaceous limestones, calcareous sandstones and marls.

Kashmir :—In this region the marine Permian strata are underlaid by freshwater black shales and sandstones with plant fossils like *Gangamopteris* and *Glossopteris*. These have a thickness of 400 feet and are equivalent of Lower Gondwana of Peninsular India.

These are succeeded by the Zewan beds formed of marine limestone with *Protoretepora ampla*, *Productus*, *Athyris*, etc. These are considered to be equivalent of the Productus Limestone Series.

The Zewan beds are followed by the Triassic which are divided into :—

(*c*) Upper Triassic Limestones.

(*b*) Middle Triassic Limestones (these have a thickness of 900 feet and are composed of limestones and shales).

(*a*) Lower Triassic Limestones.

Central Himalayas :—In this area the calcareous sandstones contain fauna of Lower Productus limestone, which

is overlaid by black siliceous friable shales, forming the Productus shales which are known as the Kuling Series, considered to be equivalent of Upper Productus limestone.

The Productus shales are succeeded by strata which have been divided into :—

(*c*) The Upper Triassic, 2,800 feet in thickness.
(*b*) The Middle Triassic, 400 feet in thickness.
(*a*) The Lower Triassic, 50 feet in thickness.

Owing to the abundance of ammonite and other fauna, each division has been further classified into a number of fossil zones.

Jurassic

The Jurassic strata of the Himalayas have been classified as follows :—

Upper Jurassic,
Middle Jurassic,
Lower Jurassic.

The Lower and the Middle Jurassic consist of limestones, 2,000—3,000 feet in thickness, and are known as the Kioto limestones which pass into Spiti shales of black colour with numerous ammonites with calcareous concretions. The Spiti shales are of Uppermost Jurassic age and extend from the Karakoram to Nepal and Sikkim.

Cutch :—The Cutch-Rajputana area underwent submergence during the Jurassic period and these rocks in Cutch have been classified into four groups, *viz.*, Patcham, Chari, Katrol and Umia. These rocks are very rich in cephalopod fossils.

Cretaceous

Central Himalayas :—The Cretaceous deposits of this region have been subdivided into :—

(*b*) **Chikkim Series :**—It consists of limestones and

shales, having a thickness of 250 feet with *foraminifera*, *Rudistae*, *Belemnites*, etc. It is of Upper Cretaceous age.

(*a*) **Guimal Sandstones :**—They consist of yellow-coloured sandstones and quartzites and are 300 feet in thickness.

Peninsular India :—Rocks of Cretaceous age occur in the south in three areas, the biggest being in the Trichonopoly district. These rocks are subdivided into four stages which are given below :—

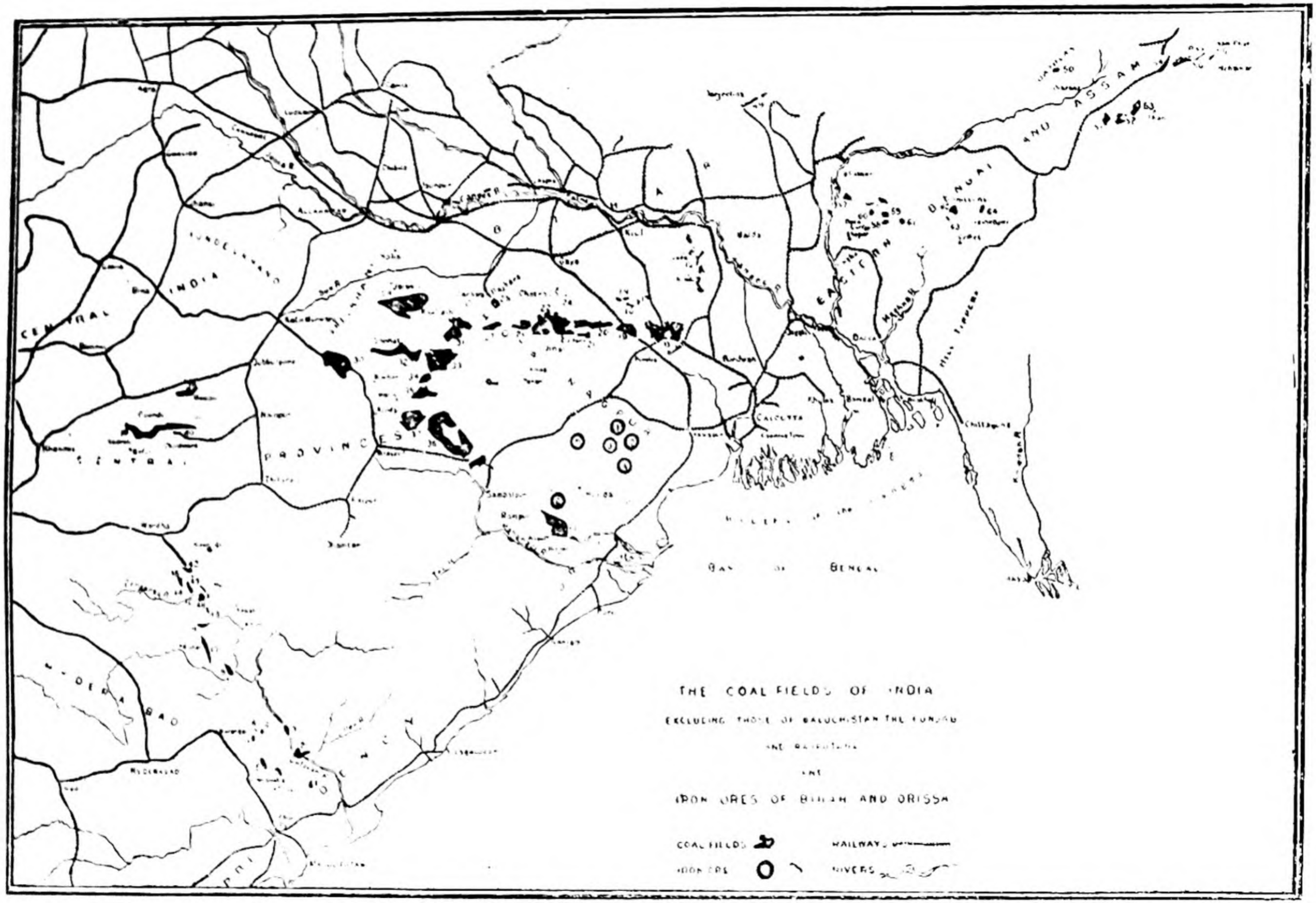
Niniyur stage,
Ariyalur stage,
Trichonopoly stage,
Utatur stage.

These rocks are reputed for their great faunal wealth. The Utatur stage, which consists of clays, silts and calcareous shales, has some economic importance as it contains phosphatic nodules which could be used as fertilizer. They occur in a low ridge east of Valudayur in the Perambalur taluka and are known to extend for about 10 miles, and the quantity of nodules available has been estimated at 8 million tons to a depth of 200 feet. The chemical composition of the nodules is given below :—

Calcium Phosphate	..	56-59 per cent.
Calcium Carbonate	..	16-20 per cent.
Silica, Alumina, Iron Oxide	..	14 per cent.

These deposits are considered as an important source of phosphates in this country.

Lameta Limestones :—The Lameta beds, which are well-developed in the neighbourhood of Jubbulpore and other parts of the Central Provinces, underlie the Deccan



Showing the disposition of the coalfields associated with the Gondwana deposits. The position of the

Trap and are hence called Infra-trappeans. Thus the fossil evidence obtained from these beds has been useful in estimating the age when the Deccan Trap was first poured forth. The Lameta beds have been classified into a number of zones and contain in places two bands of limestone which are called the Lower and the Upper Lameta Limestone, and in places they almost build perpendicular scraps. In places these limestones are partially silicified. The limestones contain about 70 per cent. of calcium carbonate, while magnesia is only 1.41 per cent. Silica is a little above 20 per cent. and the percentage of iron is extremely small indeed. The author has recently investigated the Lameta limestones of the neighbourhood of Jubbulpore and the interested reader is referred to that paper*.

The Peninsular Area

As stated above, after the Puranas there is a big hiatus until the fresh-water and terrestrial deposits of sandstones and shales with coal seams of Gondwana age were deposited on the much denuded older rocks. It is to be noted that the Gondwanas of Australia, India, Africa and South America formed a big continent called the Gondwanaland. Marine strata, however, occur only near the coast, *e.g.*, near Trichinopoly on the east and the Narbada valley on the west.

The Gondwana deposits occur in the (*a*) Rajmahal hills, (*b*) the Damodar valley in Bengal, (*c*) in the valleys of Barakar, (*d*) the Mahanadi and (*e*) the Godavari rivers. They also occur in (*f*) Orissa, (*g*) the Central Provinces, and (*h*) in the Satpura Range. They have been classified into :—

(*b*) Upper Gondwana

Journ. Geo. Min. Met. Soc. Ind., 1944, pp. 72-80.

(*a*) Lower Gondwana :—	Panchet series.
	Damuda series.
	Talchir series.

The Talchir series consist of sandstones and shales with a Boulder bed at the basc.

Economically, the Damuda rocks are the most important containing coal seams ranging in thickness up to 90 feet.

Deccan Trap

Towards the end of the Cretaceous period important changes occurred. At this time there was great volcanic activity and lava poured forth from fissures. In places these lavas have been folded, but they generally show a remarkable horizontality and form flat-topped hills, plateaux, terraces and scarps and their thickness in different places is variable. At present, they occupy an area of 200,000 square miles, but it is believed that originally these lavas were far more extensive and occupied an area of about half a million square miles. The lava erupted is chiefly olivine basalt with intercalations of Inter-trappeans comprising volcanic tuffs, ashes and some sedimentary beds. The age of these lavas is considered to be late Cretaceous to early Eocene. It is quite probable that the volcanic activity, which commenced towards the close of the Cretaceous period, ended only in the early Tertiary times. These traps furnish excellent road metal and building stone. They yield a very fertile clayey loam, which is particularly suited to the cultivation of cotton.

Tertiary Era

The end of the Mesozoic Era witnessed great changes of land and sea. It was at this time, as noted above, that the

volcanic activity of the Deccan Trap period manifested itself. It was at this time that the great Continent of Gondwana-land, which stretched from Australia through India and South Africa to South America, broke up. It is to be noted that the uplift of the Himalayas also commenced at the same time.

During the Tertiary period, two gulfs of the sea extended; one to the west and occupied the site of the provinces of Sind, Baluchistan, the Punjab, etc., whilst the other one occupied parts of Assam, etc. In these gulfs rocks of Eocene, Oligocene, Miocene and Pliocene age were deposited. Some of these rocks are of economic importance inasmuch as they include valuable deposits of petroleum or mineral oil and coal.

Sind and Baluchistan :—As stated above, the Tertiary deposits occupy an extensive area in Sind and Baluchistan. They have been classified as follows.

Manchar Series :—This series is composed chiefly of sandstones and sand-rock and is equivalent of the Siwaliks of India.	Mid Miocene to the end of Pliocene
Hinglaj Series :— It is composed of sandstones, clays and conglomerates.	Lower and Mid Miocene
Gaj Series :—The main lithology of this series is shales and limestones.	Lower Miocene
Nari Series :—It is divided into the Upper and the Lower Nari Series. The latter are composed of massive, marine limestone.	Oligocene
Kirthar Series :—This is composed of Nummulitic limestone. In eastern Baluchistan the series becomes arenaceous.	Mid and Upper Eocene

Laki Series.—It is chiefly composed of shales with coal measures. Mid Eocene

Ranikot Series.—It comprise sandstones and carbonaceous shales with gypsum. Lower Eocene

Kohat:—In this district there are masses of rock-salt and gypsum which are overlaid by Nummulitic limestone.

Salt Range:—In the Salt Range large deposits of Nummulitic limestone of Kirthar age occur.

Punjab:—At Chharat, north-west of Fatehjang, massive limestones of Eocene age occur. These pass into chalky limestones with oil-seepages. The oil-fields of Khaur and Dhulian of the Attock Oil Company, are located on these deposits.

There is a great development of the Murree beds in the Punjab and the Kashmir State. These are composed of light-coloured and purple sandstones and shales.

Simla:—In the Simla area the Tertiary rocks have a great development and have been classified as follows:—

Sabathu Series:—It consists of grey and red shales with bands of limestone. These are overlaid by the *Dagshai* Series, which are composed of bright-red clays, grey and purplish sandstones which are of Lower Murree age. At the top lie the *Kasauli* Series of Upper Murree age, which comprises chiefly sandstones.

Assam:—In the eastern gulf were deposited rocks of the Tertiary age. In the Khasi hills Nummulitic limestone occurs. In eastern Assam occur the *Barail Series* which range in age from Upper Eocene to Lower Oligocene.

Coal Measures:—They are so styled as they contain deposits of coal of Oligo-Miocene age. Oil is also associated

with these rocks and the oil-field of Digboi of the Assam Oil Company is located in them. Similarly, some of the Tertiary coal-fields of Assam occur in these rocks.

Siwalik System

The Siwalik System represents fresh water deposits and forms the range of southern foot-hills bordering practically the whole length of the Himalayas. The rocks comprise clays, sandstones and especially conglomerates and have a great thickness of 16,000—20,000 feet. They are characterised by the occurrence of the remains of the vertebrate animals of the period. These rocks have been divided into Upper, Middle and the Lower Siwaliks. The sands of the rivers draining through the region are usually auriferous, which are washed by the local people who can supplement their income by devoting their leisure hours to this pursuit.

Pleistocene and Recent

Indo-Gangetic Alluvium:—The deposits, comprising the Indo-Gangetic alluvium along with those of the Brahmaputra, which make up the vast plains stretching from Assam in the east to the Punjab in the north-west, represent the sediments brought down from the Himalayas by these rivers and their affluents. They include great thickness of clay, loam, silt, etc. They have been divided into (*a*) the Older Alluvium and (*b*) the Newer Alluvium. The Older Alluvium represents the ground above the present flood level of the rivers and is called *Bhangar*. Calcareous concretions of kankar are very common in these deposits. The Newer Alluvium is confined to the river channels and their flood plains and is locally termed as *Khaddar*. Every year new silt is laid by the rivers which makes a very fertile soil for the growth of crops, when the high water has receded after the floods.

The thickness of these alluvial deposits is great as some of the deepest borings have not touched the rock bottom. This area from the human point of view is the most important and interesting. It forms a very fertile region and with the aid of irrigation, produces the agricultural raw materials, etc., of Northern India.

CHAPTER XVI

THE MAKING OF INDIA

A brief idea of the geology of India has already been furnished. It is now proposed to give a concise account of the gradual building of this country which may be beneficial to a student of geography and geology. This will also give a chronological sequence of the important events of the changes of land and sea, which led to the gradual shaping of the present topography of this land.

Peninsular India

The primeval crust of the earth is represented by some of the gneisses and other igneous rocks which build almost the whole of Peninsular India. After their development, some of the area was submerged under the Dharwar sea and by the denudation of the Archæan rocks the ancient unfossiliferous sediments, now represented by the various kinds of schists, quartzites, slates, limestone and marble, were laid. It is noteworthy that the gold of Mysore, etc., manganese of Central Provinces, etc., and the iron ores of Bihar are associated with some of these rocks. At the close of the Dharwar period these rocks were subjected to severe dynamic stresses with the result that they were highly folded, contorted and subsequently subjected to denudation.

The highly folded and denuded rocks of the Archæan Era were submerged under the Cuddapah sea in parts of Peninsular India. On the eastern side of the peninsula these rocks occupy an area of 14,000 square miles and comprise quartzites, sandstone, slates and limestone. The latter can be taken out in large flags which are used very largely for flooring and other building

purposes. This limestone also finds use in the cement industry as at Shahabad in Southern India.

In Central India and in the eastern districts of the United Provinces, particularly Allahabad, Banda and Mirzapur districts, Vindhyan rocks were deposited. These comprise sandstones, shales, limestones and conglomerates which represent two distinct diamond-bearing horizons. These rocks are of great economic importance and have furnished important building materials to many large and small architectural works. They have been employed extensively in raising the buildings of the capital city of India and numerous historic monuments to be seen at Fatehpur Sikri, etc. The limestone found in these rocks is also equally important. Near Katni, Sutna, etc., these flaggy limestones are quarried and are burnt to produce lime of good quality, which is used so extensively in various industries in different parts of India.

Aravalli Mountains :—In Rajputana sediments equivalent of the Dharwar period were deposited, which at its close were uplifted into the great Aravalli Range, which represents the most ancient tectonic mountain of India. There is evidence to prove that it was further uplifted during the early Palæozoic times. It extended from the Deccan to the Himalayas. It was considerably loftier and more extensive, but has now been greatly reduced by denudation. In places, copper deposits with extensive old copper workings are to be observed.

Gondwanaland

After the deposition of the Cuddapah and the Vindhyan rocks, there is a great hiatus until fresh water and terrestrial deposits of sandstones and shales, comprising the Gondwana rocks, were deposited. It is concluded

that owing to crustal movements large blocks of land were let down between vertical or almost vertical fissures, and new drainage, established along these depressed tracts, began to pour detritus, where, consequent upon accumulating load, sedimentation and subsidence, with respect to the surrounding Archæan or Vindhyan rocks, went on together. Thus indeed a great thickness of the Gondwana rocks was deposited in these basins. It has been referred to above that the vast coal deposits of India were laid in the Lower Gondwana rocks. It is due to the deposition of the rocks in the sinking areas that these economically important deposits were saved from the agents of denudation to which they would have been otherwise greatly subjected. This fact has also been responsible for their not having been subjected to folding, crushing, etc.

During Gondwana times there was undoubtedly land connection with Africa. In the north the sea occupied the present site of the Himalayas and the east coast-line had almost assumed its present outline.

Climatic Changes:—It is remarkable that during Gondwana times there were very marked changes of climate. They commenced with a very cold episode, and the occurrence of a glacial boulder bed at the base of the Gondwanas, referred to above, is a well-marked horizon in the geology of Peninsular and Extra Peninsular India. There is a corroborative evidence forthcoming from the adjoining continents of Australia on one hand and South Africa on the other. In the overlying rocks thick coal seams occur, and these point to a much warmer climate when the vegetation was very prolific. In the succeeding Panchet series there is evidence of another cold cycle. The rocks overlying those of the Panchet series give proof of an arid climate.

The coalfields of the eastern part of the Damodar valley of Bengal show signs of igneous activity after the deposition of the coal-bearing rocks. They have been invaded by intrusions of an ultra-basic rock, called mica-periodotite and these have been responsible for coking or even burning of some of the adjacent coal.

Rajmahal Volcanic Outbursts:—During the deposition of the Upper Gondwana rocks volcanic erruptions manifested themselves, particularly in the Rajmahal hills, where bedded basalts attaining a thickness of 2,000 feet were poured forth during the Jurassic times. In these volcanic rocks there are intercalations of sandstones and clays which are called inter-trappeans. The basalt is of dark colour with a porphyritic and amygdaloidal structure and is generally fine-grained. In places it is coarse enough to be styled a dolerite. A connection between the Rajmahal traps and the intrusions of the mica-periodotites of some of the Bengal coalfields has been suggested, and thus the latter are the hypabyssal equivalents of the Rajmahal lavas. The Rajmahal beds, *i.e.*, greyish silicified shales have yielded a very prolific fossil flora in which many genera of Cycads predominate. The flora of these beds is remarkably different from that of the Lower Gondwanas. An account of volcanic activity during Upper Gondwana times has been given in Chapter IX.

Marine Transgressions

Permo-Carboniferous Marine Transgression:—During Permo-Carboniferous times there is a testimony of a very brief invasion of the sea. At Umaria in Central India, a thin band of Productus limestone with *Spiriferina* and *Reticularia* (which are definitely marine fossils) is found intercalated in the fresh water coal-bearing desposits of the Lower Gondwana age. This fauna is believed to be

unique and shows no affinities to the Salt Range fauna but is rather comparable with the Himalayan fauna.

This is indeed a solitary record of the invasion of sea into Central India or the heart of the peninsula. It has been suggested that either this invasion came from the north through Rajputana or from the west coast. But it is noteworthy that this invasion was extremely evanescent.

Upper Cretaceous Marine Transgressions :—On the south-east of the Coromandel coast of Peninsular India occur some very interesting rocks of Upper Cretaceous age. At this time occurred a great marine transgression which has left its mark in three separate areas; the largest and the most southerly, occurring in the Trichinopoly district, has an area of two to three hundred square miles. These deposits contain a very rich fauna including more than a thousand extinct species of invertebrates. They help in the elucidation of the distribution of land and sea at this time. Their comparison with the fauna of India and Africa reveals the geography of Gondwanaland at this time.

Likewise, records of a similar transgression have been preserved in the marine Cretaceous rocks, *viz.*, the Bagh beds of the Narbada Valley. A group of these detached outcrops extends in an east-west direction from the town of Bagh in the State of Gwalior to Wadhwan in Kathiawar Peninsula. This incursion of the sea occurred from the Tethys in the north and it is contemporaneous with the marine transgression of the south-east coast referred to above. The limestone and marls, which are richly fossiliferous, comprise only a thickness of 60-70 feet.

Deccan Trap Volcanic Activity :—Volcanic outbursts of basic lavas towards the close of the Cretaceous period have been referred to above. It was at this time

that numerous rectilinear fissures were formed in a large part of the Peninsular region, when it was flooded by huge and numerous flows of lava which have built a large plateau. These lavas are known as the Deccan Traps. The extent and thickness of these lavas has been given in Chapter III. These lava flows have intercalations of sedimentary strata which have only a small vertical and horizontal extension and are known as inter-trappean beds. They are of lacustrine or fluviatile origin and are fossiliferous. The plant fossils and fresh water molluses, fish, frogs, tortoises, in the intertrappean rocks have furnished a history of the dormant periods of this volcanic activity, when these deposits were laid. The preserved plants comprise both palms and dicotyledonous wood, fresh water alga *Chara* and fresh water fern *Azolla*.

The end of the Mesozoic or the commencement of the Tertiary Era brought about important changes in the geography of India. It was at this time that the Gondwanaland broke up and by the submergence of the intervening portions, it became detached from Africa and the present regular, wall-like outline of the west coast of India was formed. The Arabian Sea from the coast suddenly plunges into depth and proves that the sea occupies a basin of subsidence. The huge, contemporaneous volcanic outbursts of the Deccan Trap occupying a vast region and building a huge plateau have been referred to above. It was also about this time that the Himalayas were first upheaved from the bottom of the sea. Some authors are of the opinion that the Indo-Gangetic depression also originated at the same time concomitantly with the Himalayan uplift. In brief, Peninsular India assumed almost its present shape, which has not altered much since then.

During the Tertiary Era, some deposits were laid in the Peninsular region. The northernmost are those of

Rajputana where the Nummulitic limestone occurs west of the Aravallis. This is underlaid by shales containing seams of lignite and bituminous coal.

The Tertiary rocks, ranging in age from Oligocene to Pliocene, occur at the eastern and western extremities of Kathiawar peninsula. As sporadic occurrences of natural hydrocarbon gas have been found near Baroda and the coast of Kathiawar, it is presumed that the earlier Tertiary rocks, representing the petroliferous horizons of the Punjab and Assam, occur underneath them.

On the east coast of India, deposits of late Tertiary age extend from as far north as Orissa to the town of Cuddalore in the south, and are known as Cuddalore Series. Similar rocks are found on the Travancore coast, and are known as Warkalli and Quilon beds.

After the Tertiary Era, alluvial deposits were laid on the coastal regions, particularly on the east coast, which is broader than the west coast. Finally, came the formation of the delta regions which comprise those of the Mahanadi, Godavari, Kistna and Cauvery, referred to above. With the help of irrigation these deltas represent some of the most productive lands of the region.

The Himalayan Region

As noted already, it was in the early Tertiary times that the Himalayas were gradually uplifted from the bottom of the sea. The site of the present Himalayas was occupied by the sea called the Tethys, which at that time extended from the European Alps to beyond the eastern extremity of the Himalayas, and sedimentation since the Cambrian times was almost continually going on in this region, called the Himalayan geosyncline. It was only in the Carboniferous period that there was a break in this deposition, when there was an uplift, but the land was soon submerged under the sea again. During the whole of the

Palæozoic and Mesozoic Eras, a vast pile of sediments, about 20,000 feet in thickness, was laid here. It must be noted that for the accumulation of the above load, sedimentation and subsidence kept pace in this geosyncline. The upheaval of the Himalayas took place in three stages. During the first stage the central axis of the Himalayas, comprising the old sedimentary and crystalline rocks, was upheaved. Owing to this uplift the sea receded into only a few basins, where the Nummulitic limestone was deposited. The second stage was about the middle of the Tertiary Era (Mid-Miocene) when the central part of the range was upheaved. The third phase came at the end of the Tertiary time, when the Sub-Himalayan zone was added. This phase continued even into the present era when the Boulder Conglomerate deposits of the Pleistocene age in the very outer ranges of the hills and the Karewas were disturbed.

It is remarkable that the Himalayas are still rising, which is apparent from a number of facts. First is the frequency and the severity of earthquake shocks, which show that the region is still unstable and has not attained its final equilibrium. Secondly, the desiccation of the lakes of Tibet within Recent or even historical times is another decisive proof of the further uplift of the Himalayas, which have cut off the passage of the monsoon winds on to this region. Surrounding these lakes, sand and gravel terraces at higher levels, sometimes 200-300 feet above the present water-level, are to be seen, proving that within comparatively recent times water stood at much higher levels. Thirdly, the rivers of the Himalayas are quite young and immature and have been rejuvenated in recent times.

Tertiary Gulfs :—It is noteworthy that in the Tertiary Era with the uplift of the Himalaya and the recession of

the Tethean sea, two gulfs extended into the Extra Peninsular region: one into the north-west and the other into the north-east. These gulfs by the pouring of the sediments by the predecessors of the present rivers, gradually retreated to the south. The Tertiary rocks of Sind, Baluchistan and the Punjab were deposited in the gulf on the north-west and the Tertiary rocks of Assam were deposited in the Assamese gulf, which extended from the Arakan coast to the extreme north-east of Assam. It is noteworthy that it is in these gulfs that the only petroleum deposits of the north-west and the north-east, along with those of the associated Tertiary coal, were laid. As the gulfs were gradually silted and receded to the south, the older deposits of the higher regions gave place to newer rocks.

Indo-Gangetic Plains

Finally comes the consideration of the Indo-Gangetic plains. As noted in Chapter I they represent the youngest physiographic division of India and separate Peninsular India from the Himalayan region, and occupy an area of about 250,000 square miles. These plains are composed of the sediments deposited by the three great river systems of Northern India, *viz.*, the Indus, the Ganges, and the Brahmaputra rivers. Geologically, the area is not very interesting but it furnishes some of the best soils, which have supported agriculture for about 5,000 years and yet show no sign of exhaustion. These plains represent the most densely populated region of India, in fact one of the most densely peopled regions of the world. In other words the pressure of population on this region is very great indeed.

The plains are divided by a narrow ridge near Delhi, which is really a northern continuation of the Aravalli mountains. It may be further noted that geodetic in-

vestigations have revealed below the Indus alluvium the existence of a ridge which runs parallel to the Himalayas from Delhi to the Salt Range and the visible parts of this represent the Sangla and the Kirana hills.

Nature of the Depression :—Various hypotheses have been advanced to explain the origin of the Indo-Gangetic depression. It is apparently a synclinal basin which was formed as an accompaniment of the uplift of the Himalayas. Suess, the well known Geologist, was of the opinion that the Indo-Gangetic trough represents the fore-deep, when the Himalayas were upheaved from the bottom of the Tethean sea. With the concomitant sinking, the Indo-Gangetic trough originated, which is partly original and partly due to subsidence brought about as a result of deposition of the great load of alluvium. As stated already, Peninsular India represents a stable land-mass, while the region of Central Asia, including the Himalayas, has undergone great compression and thrusting.

Sir Sydney Burrard considered that these plains conceal a subcrustal crack or a rift valley which stretches for 2,000 miles along the foot of the Himalaya and is bounded by parallel faults or dislocation on either side.

Another hypothesis represents this area as a sag in the earth's crust, developed between the compressed sediments of the Himalayas and the northward drifting Indian Peninsula, at a time, when the mighty ranges of the earth came into being. This hypothesis finds favour with many geologists. It is concluded that the depression was initiated in Upper Eocene times, and had its maximum development with the second phase of the Himalayan upheaval in Mid-Miocene times. It is likely, as noted already, that the disruption of the Gondwanaland, uplift of the Himalayas, and the depression of the Indo-Gangetic

plains occurred almost simultaneously. Some authors, however, are of the opinion that this depression originated as late as the Pleistocene, but its origin during the Mid-Miocene time finds greater support. It began to be subsequently filled up by the alluvium of the predecessors of the present rivers which gradually extended on to the sea.

Depth of the Depression :—In general, the depression has its maximum depth within a short distance of the Himalayas and becomes gradually shallow towards the Peninsula. A few borings, put down in search of artesian water, have failed to touch the bottom and the thickness of the alluvial deposits, deduced from geodetic observations, is about 6,500 feet, but this estimate is considered too low by geologists. R. D. Oldham concluded that the maximum depth of the trough was 15,000 feet near its northern edge. According to Sydney Burrard the rift, south of Mussoorie, has a depth of 20 miles.

Isostasy and Mountain Compensation :—The Himalayas and the Indo-Gangetic depression bring us to the problem of isostasy and mountain compensation. Isostasy means a tendency to restore equilibrium in the crust of the earth. It has been found by plumb-line observation by the Geodetic Survey of India that at a short distance away from the Himalaya, the plumb-line is not deflected towards the mass of the mountains but towards the Indo-Gangetic plains. At Kaliana, which is only 50 miles from the Himalayas, the mountains have no effect on the plumb-line. It has been suggested that the rapid decrease of the northerly deflection of the plumb-line is due to the occurrence of an invisible chain of high density which runs parallel with the Himalayas at a distance of about 150 miles from the foot-hills.

Thus the great mass of the Himalayas is underlaid by lighter material, while the depression of the Indo-Gangetic plains has denser material underneath it. This phenomenon, which is universal, is called 'mountain compensation', as other bulges or bumps of the earth like mountains, plateaux and continents are underlaid by material of deficient density, while the ocean basins have denser material lying underneath them. This condition of approximate equilibrium is styled isostasy and such a compensation by the density of the material is called 'isostatic compensation'. The depth at which the isostatic compensation is complete, is called the 'depth of compensation'. For the United States of America it has been calculated to be about 76 miles but in the case of India, the figures are variable, as Extra Peninsular India is still in an unstable condition and has not gained its final equilibrium.

Deltaic Regions Still Extending :—It is noteworthy that these rivers bring a colossal amount of detritus with them, particularly during the rainy season, when the rivers are in spate. A considerable part of these sediments reaches the sea, and thus the land is gradually gaining on the sea. The Sundarbans are no doubt gradually extending to the south.

Economic Importance of the Plains :—It is hardly properly realised what a great economic importance these plains possess. The furnishing of fertile soils has been mentioned already. The plains, excepting kankar, possess no building material or road metal. Although it is familiar that the alluvial materials of the plains, *viz.*, the earth and sand are made into brick, the universal building material in the plains, the author had not realised the extent of this brick manufacture until he was engaged in making an industrial survey of the United

Provinces. To his great amazement he found that in some of the important district towns, crores of bricks were manufactured every year during the dry season and these bricks, in terms of value, yield annually a colossal amount of money, when it is calculated for the total area of the plains. Likewise, *kankar* of enormous value is extracted every year from innumerable localities in these plains. It is burnt for lime and is also used as a road metal. Block *kankar* is even employed as a building stone. Huge quantities of saltpetre are manufactured annually from nitrous earth in the plains of the Punjab, the United Provinces and Bihar. Likewise, large quantities of *reh* are collected from the *usar* lands of the U.P. and *kalkar* of the Punjab. *Reh* is extensively used in laundering clothes and in the manufacture of crude glass. *Sajji* (a crude form of sodium carbonate) and sodium sulphate are also manufactured from similar lands in the plains. Again, the extent of the quantity of sand, which is collected from the bed of these rivers during the dry season for building purposes, is hardly realised.

CHAPTER XVII

SOILS

The importance of the study of soils to a country like India, where a great majority of the population depends upon agriculture, hardly needs any emphasis. The question of soils is important to agriculturists, horticulturists, and Forest Officers; the latter have to deal with the creation of new forests and the maintenance of the existing ones. Unless the nature of the soils is properly understood, it is not possible to have maximum yield from them.

Soil represents the top portion, *i.e.*, the uppermost layer of the earth's crust, which provides organic and mineral matter so essential for plant growth. If developed *in situ*, it is derived from the gradual decay of rocks under the influence of the agents of sub-aerial weathering. Generally, a transition between the rock, the subsoil and the soil is to be observed. Thus in the development of a soil and its properties, various factors, for example, the parent-rock, relief, climate and particularly the rainfall, its age, plants and animals play an important rôle. The physical divisions, the geology and the climate of India have been discussed in some of the foregoing chapters. It has been already pointed out that India enjoys a monsoon climate, *i.e.*, there is a wet season from June to October, followed generally by a long dry season. Such a type of climate must have an important influence in the development of Indian soils.

The soils of India can be classified into two broad subdivisions.

(*1*) The transported or the drift soils, which have been deposited by some agency, *e.g.*, the running water,

etc., in their present position. To this group belong the soils of the Indo-Gangetic plains. Associated sometimes with this group are the alkaline lands, and their reclamation is an important topic of the day.

(2) The *in situ* soils comprise those which have been developed in their present position. They include the soils of Peninsular India as also those of the Himalayan region.

Geographically, the soils of India can be sub-divided into three main groups, based on the fundamental physiographic divisions discussed in the first Chapter. The different soils of these regions possess their own distinctive characteristics, based on the nature and age of the mother-rock, position, relief, climate, vegetation, etc. Thus we have the following three main groups:—

(1) The Soils of Peninsular India.
(2) The Soils of the Indo-Gangetic plains.
(3) The Soils of the Himalayan region.

A soil map of India has been recently published by the Imperial Institute of Agricultural Research, New Delhi, which is reproduced on a reduced scale in Fig. 17.

Soils of Peninsular India

As noted already, the Peninsular region is the most ancient land-mass of India and a great portion dates back to the Archean times. The soils of Peninsular India are therefore very old and highly mature. Three main types of soils occur in this region, which are as follows:—

(1) Red soils.
(2) Black Cotton soil.
(3) Lateritic soils.

These soils, which show a great variation in their texture, structure, moisture and humus content and clay-factor, are described below.

Red Soils

Distribution :—These soils have an extensive distribution in Peninsular India, covering the whole of Madras, Mysore, South-east of the Bombay Presidency, eastern part of Hyderabad-Deccan, the Central Provinces, Orissa, Chota Nagpur, etc., and occupy an area of 800,000 square miles. It represents the most extensive soil-group of India. These soils are associated with the gneisses, granites and schists and these rocks also occur in Bundelkhand, the Aravalli region of Rajputana and in Assam. However, the soil in these regions is not of uniform colour. For instance, these soils may be red, yellow, brownish or even grey to black in colour. It also varies in consistency and depth. These red soils in places merge into laterite. The soil of the Salem, Trichinopoly, Tanjore and South Arcot districts in the Madras Presidency is red in colour and is largely sandy, but is not uniformly consistent in different regions.

The soil covering the Cuddalore sandstone is usually highly ferruginous, but occasionally it becomes clayey, and sometimes has a pale yellow to greenish-brown colour.

In places the soil has a thickness of four feet or more and is very fine-grained, but becomes coarse in places. Where granite is the parent-rock, it becomes a coarse dry soil with a reddish or brownish colour, as is the case in a large part of the district of Trichinopoly. Wherever hornblende occurs, the soil has all shades of red colour, but wherever magnetite is present, the soil has a darker tint.

Origin of Red Soils :—These red soils are characteristic of tropical regions. The red colour is attributed to the diffusion of ferric oxide and its distribution is ascribed to alternating wet and dry seasons. It is considered that during the mild, wet season, humus is destroyed and during the dry

season, by capillary action, the iron oxide is precipitated after the evaporation of water. This soil is mainly formed by the decomposition of somewhat ferruginous, particularly hornblendic rocks.

Characteristics of Red Soils :—The soil varies from place to place, depending upon the nature of the underlying rocks. The upland soils are generally light, thin and gravelly, while those of the plains and valleys are deeper in tint and have a greater fertility. These soils are poor in humus, while nitrogen and phosphorus are also low. The soils, which are derived from acid gneisses, are poor in phosphorus, nitrogen, lime, magnesia and humus, but are rich in potash. The soils derived from boitite-and hornblende-rocks have a high iron content, while the soils associated with basic and ultrabasic rocks are rich in magnesia. Generally, this group is poor in soluble exchangeable bases.

Chemical Composition :—The following analysis gives the chemical composition of red soils from Madras.

Insoluble matter	90.47
Alumina	2.92
Ferric Oxide	3.51
Lime	0.56
Magnesia	0.70
Soda	0.12
Potash	0.24
Phosphoric acid	0.09
Carbon dioxide	0.30
Water and organic matter	1.01
	99.92

The soil has low organic matter and other plant nutrients.

Black Cotton Soil or Regur

The Black Cotton soil of India is believed to form the second important soil-group of Peninsular India. It is so named because of its dark colour, and also because it is very suited to the cultivation of cotton. The term *regur* is also applied and is derived from *Regada*, the Telegu for black soil.

Distribution :—It occupies a large area in Bombay, the Deccan, the Central Provinces and Berar, parts of Gujarat and Kathiawar. In these areas this soil is formed from the Deccan Trap or the alluvium derived mainly from it. It occupies large areas in the Madras Presidency covering the districts of Bellary, Kurnool, Cuddapah, Anantpur, Guntur, Coimbatore, Trichinopoly, Salem, Tinnevelly, etc., and here they are generally associated with basic gneisses and schists which occur with other acid gneisses of this region.

Origin :—The origin of this soil has received the attention of several investigators including Newbold, Hislop, W.T. Blandford, Oldham, Luther, etc. The earlier workers considered that this soil had been formed by the surface alteration of the Deccan Trap.

Theobald, while discussing the origin of this soil, stated : "With regard to the origin of *regur* no one who has examined any portion of the Trap area in the vicinity of the Narbada can entertain a doubt, any more than regarding the origion of the Trap pebbles so plentifully distributed over the valley. It is apparently a deposit derived from the decomposition of Trap rocks. Though perhaps modified to some extent in different quarters by local conditions and the varied and mixed composition and characters of the rocks in the vicinity, yet, whenever a sufficient expanse of level ground occurs, within or near

the Trap area, to permit of its accumulation, there do we find *regur* under conditions which clearly point out its origin from the decaying Trap rocks surrounding it". This soil in the river valleys and the areas, adjoining the trap, is deposited by the weathering of the trap. The author observed this soil near Itarsi and again near Raj Nandgaon in the Central Provinces. These soils were definitely alluvial in character, but yet they possessed almost all the characteristics of the Black Cotton soil. It has also been advanced that in regions where this soil occurs but is not directly underlaid by the trap, the trap rock once may have extended to these areas. It is to be noted that whenever virgin soil is observed on the trap, it has a distinctly reddish or brownish appearance, but on cultivation it assumes a dark grey or black colour, apparently owing to admixture with humus.

Hislop suggested that *regur* was of subaerial origin and the characteristic black colour was produced by the assimilation of humus by different argillaceous soils. This view was also confirmed by W. T. Blandford. Undoubtedly, some of the *regur* has resulted by the decomposition of the trap, but it is probable that in places it is derived from other argillaceous rocks, *e.g.*, basic gneisses and crystalline schists of the Madras Presidency. In some places it may be formed from alluvial clay deposited in river valleys, etc.

It will therefore be seen that the Black Cotton soil can be classified into two, rather three varieties, *viz.*, (*i*) the black soil associated with the Deccan Trap, (*ii*) the black argillaceous alluvial soil derived mainly from the Deccan Trap and possessing characteristics similar to (*i*) and (*iii*) the black soil associated with the basic gneisses and schists of the Madras Presidency.

Important Features :—As this soil is associated with different geological formations, it varies naturally in colour, but it, however, possesses special characteristics. It is invariably highly argillaceous and somewhat calcareous. When moist, it is highly adhesive and on drying it undergoes a remarkable contraction, so much so that in the dry season it is extensively fissured. Some of the cracks may measure a few inches in width and several feet in depth. It can retain moisture well and therefore it does not require irrigation to the same extent as the loamy or sandy soils. Although *regur* is generally devoid of pebbles but it may contain prolific concretions of *kankar*. it may contain small nudules or fragments of chalcedony or zeolites in the trap area. The soil is usually deep. It is generally fertile and may not require manure for considerable time.

Chemical Composition :—The chemical composition of *regur* is not fully known but the following partial analyses will give some idea :—

	I	II	III
Insoluble	68.71	56.11	65.16
Potash	0.45	0.39	0.14
Soda		0.23	0.01
Lime	1.82	6.59	2.18
Magnesia	1.79	2.51	2.47
Ferric oxide ..	11.25	9.83	9.27
Alumina	9.39	10.68	13.76
Phosphoric acid ..	0.06	0.08	traces
Carbon dioxide ..	0.44	4.18	0.91
Water & Organic matter	5.83	9.47	5.85
Total ..	99.74	100.07	99.75
Nitrogen ..	0.05	0.03	n.d.

I. Soil from Nagpur Farm, analysis by Luther.

II. Soil from Akola Farm, analysis by H.E. Annet.

III. *Regur* from Trichinopoly, analysis by Luther.

These analyses reveal that these soils are rich in iron, alumina, lime and magnesia; organic matter is also appreciably present. It is, however, low in phosphorus, nitrogen and the potash-content is variable. Its base-exchange capacity is fairly high.

Colour of the Soil:—A number of theories have been advanced to explain the dark colour of this soil. Oldham suggested that the characteristic colour of this soil was due to an admixture of vegetable humus with the clayey soil. Theobald, however, did not agree with this theory and stated that the black colour was due to some superficial condition of the iron of some component of the rock.

H. E. Annet, after careful investigations, arrived at the conclusion that black colour of this soil was owing to the presence of titaniferous magnetite coupled with one to two per cent. of soluble humus. This soil is not rich in organic matter and the percentage of clay is very high indeed.

Messrs. Harrison and Ramaswamy Sivan made investigations on the Black Cotton soils of the Central Provinces, the Bombay and Madras Presidencies and concluded that while titaniferous magnetite was appreciably present in the soil associated with the Deccan Trap, the soils of the Madras Presidency were entirely devoid of it. They arrived at the conclusion that the colour was due to soil particles having low sepecific gravity. The mechanical analyses of South Indian soils revealed that the finer fractions have a black tint. The microscopic examination revealed the composite nature of these particles

which consisted of small transparent or semi-transparent grains cemented together by a dark-coloured matrix, which was found to be colloidal, amorphous material. It is a double hydrated iron and aluminium silicate.

Laterite and Lateritic Soils

Laterite is derived from *later*, meaning brick, and this term was introduced by Buchman in 1807, who first came across this rock during his travels in Malabar, Kanara and Mysore territories. It has a very wide distribution in the Deccan. The laterite is of two varieties: (1) the high-level laterite and (2) low-level laterite, which is generally of detrital character and is derived from the disintegration of the former. The high-level laterite, as observed in parts of Bihar, etc., overlies bauxite. It is a primary ferruginous laterite, which is definitely a surface formation, and which sometimes forms very steep escarpments. Wherever the soil has been washed away it forms a hard pan with the characteristic rough, vesicular appearance. The vesicles are formed by the removal of the softer material. It is dark-brownish or yellowish-red in colour with patches of grey aluminous material.

Occurrence and Distribution :—Laterite occurs in tropical regions and is found associated with a variety of rocks. It is derived from igneous, sedimentary and metamorphic rocks. The author has observed laterite associated with igneous rocks ranging from granite to peridotites. It is widely found capping basalts. It is also observed on sandstones and shales. Likewise, it is also seen capping schists, particularly basic schists and gneisses. In India it is found associated with monsoon climate characterised by alternating wet and dry seasons.

The laterite, capping the hills and plateaux, is called the primary or high-level laterite and is not found below

2,000 feet above sea level. The low-level or secondary laterite, which is formed by the denudation of the primary laterite, is found on the coastal areas of the Peninsula. Owing to the flat charac er of the eastern coast it is widespread, while on the Malabar coast it occurs in isolated patches.

Origin of Laterite :—As laterite is found associated with a great variety of rocks, its origin is somewhat disputed. It is, however, agreed that the silicate minerals are decomposed and some of the constituents are leached out with the formation of kaolin or its variety lithomarge. The hydrated silicates are further decomposed and the remaining two molecules of silica are removed with the formation of aluminium hydroxide and ferric hydroxide. The latter compound is sometimes subsequently introduced by meteoric waters, particularly when laterite caps bauxite.

The conditions favourable for the formation of laterite are as follows :—

(1) A tropical climate with an alternating wet and dry season.

(2) A flat-topped elevated region with very gentle slopes which will prevent any marked erosion.

(3) Rocks of proper mineral and chemical composition.

(4) The rocks should be somewhat pervious or they should be well-jointed.

Chemical Composition :—Laterite has a very variable composition. It is an admixture of hydroxides of iron and aluminium. A typical laterite is composed of 50 per cent. of limonite, and the balance is composed of trihydrate of aluminium. The chemical accessory constituents of laterite are silica, titanium dioxide, lime

and magnesia. These are present only in small proportions. Alkalies, potash and soda are generally absent. The proportion of silica varies with the parent-rock. In case the laterite is derived from a granite, the percentage of silica is naturally high, but when it is derived from basic rocks its percentage is low. Not infrequently, the clay-base of lateritic soil is composed of free alumina mixed with sesquioxide of iron. In the following table, the chemical analyses of laterite from different localities in India, are given :—

		I	II	III
Silica	..	0.37	17.08	32.62
Alumina	..	43.83	20.83	25.28
Ferric Oxide	..	26.61	39.09	17.28
Ferrous Oxide	..	....	0.98	0.79
Magnesia	..	....	....	....
Lime	..	0.89	0.30	0.42
Phosphorus pentoxide	..	....	0.07	....
Titania	..	4.45	1.72	1.92
Loss at 105°	..	....	2.49	1.76
Loss at red heat	..	23.88	11.05	11.86
Insoluble in sulphuric acid	..	....	6.67	8.15
Total	..	100.03	100.28	100·08

I. Tarkesar, near Surat, Bombay Presidency.

II. Cheruvanner Quarry, Malabar.

III. Tellicherry Club-Beach.

The laterite soils are very poor in lime and magnesia. Their phosphorus, nitrogen and potash contents are also low. Having developed in monsoon climate, their leaching is thorough, and thus their exchangeable bases are also removed. Thus these soils have poor fertility and are not very suitable for purposes of cultivation.

Nature of the Soil:—The lateritic soils have a variable composition. On the hills, plateaux, etc., the soil is generally gravelly and owing to its porous character cannot retain much moisture. The following observations made by the author on some of the plateaux west of Lohardaga would give an idea of the lateritic soils at least in the Ranchi district of Bihar. On the plateau and near its edge there is a layer of soil with small ferruginous concretions or iron pellets. Its thickness is about 10 feet in the middle but near the edge of the plateau, it is sometimes only $1\frac{1}{2}$ feet. On the top of the plateau, terraced fields have been cut and sometimes as many as a series of five such terraced fields is to be seen. The soil is clayey and is yellowish to reddish-yellow in colour. The following colour section was observed in a profile in descending order :—

(*i*) Yellowish clayey soil,

(*ii*) Yellowish red clayey soil,

(*iii*) Deep-red sub-soil.

The secondary laterite yields dark heavy loams and clays which can retain sufficient moisture and are better suited to agriculture than their high-level equivalents.

Alluvial Soils of Peninsular India

Alluvial soils occur along the coasts of the Peninsula. Some of these are of lateritic origin and may comprise the low-level lateritic soils, but large areas are occupied by alluvium along the valleys and at the mouths of the important rivers of Peninsular India, *viz.*, the Mahanadi, Godavari, the Kistna and the Cauvery. These soils are derived by the weathering and disintegration of the rocks occurring in the catchment area of these rivers, but they usually comprise heavy loams. They contain adequate amounts of potash and lime, but are deficient in nitrogen,

phosphoric acid and humus. These soils with the aid of irrigation yield very good crops of sugar-cane, rice, etc.

Indo-Gangetic Alluvial Soils

The Indo-Gangetic alluvium, forming the great plains of Northern India, is composed of the sediments or detritus brought down by the Himalayan rivers. It extends from Assam in the east to the delta of the Indus in the west and comprises an area of about 250,000 square miles and geographically, covers a large part of Sind, the Punjab, the United Provinces, and parts of Bihar, Bengal and Assam. The width of these plains varies from 300 miles in the west to 90 miles in the east.

Classification of the Indo-Gangetic Alluvium :—
These alluvial deposits can be sub-divided as follows :—

(*i*) Newer Alluvium,

(*ii*) Older Alluvium.

The deltaic areas of the Indus and the Ganges from pedological point of view may constitute a third sub-division.

Usually these soils are considered monotonous showing little variety, but a soil survey of the area of the Benares Hindu University and the neighbourhood carried out by the author and Mr. Y. K. Agarwal revealed some very interesting facts. The survey revealed that the soils included (1) sandy loam, (2) loam, (3) clayey loam, (4) clay, (5) silt, (6) sand, (7) patches where *kankar* predominated and (8) *usar* lands. It was definitely found that a clayey loam represented a much better soil than a sandy loam. Several profiles were dug in this area and carefully examined. Careful chemical analyses of some of these soils were made, some of which are given below. Mineral composition of these soils was also carefully examined which involved washing of several samples

from different localities and horizons. These mineral residues were separated into light and heavy fractions with the help of bromoform. These were mounted on slides and examined under the microscope. The examination of the mineral compostion is important, as the soil and the clay-factor are ultimately derived by the decay and decomposition of these minerals. Ground water conditions were also examined, which revealed the existence of two distinct types of (1) shallow and (2) deeper wells. It is definitely not within the scope of the present treatise to dwell on this work here any further, but it would appear that much research can be usefully done on these soils.

Older Alluvium :—The Older alluvium is represented by the practically level plain above the flood-level of the main rivers and their tributaries. The predominant material is a elay which, in admixture with particles of quartz and mica, becomes a loam, sandy loam, etc. The calcareous *kankar* is invariably interstratified at different levels. In some of the profiles dug near Benares, it was noticed that the upper portion consisted of mottled bluish clay, while lower down, and when freshly cut and moist, it showed a somewhat greyish colour, but this on drying assumed a definitely yellowish tint. Besides, clays of reddish and bluish colour were also noticed.

Sometimes it was observed that in hard clayey soil with a yellowish appearance, abundant small black or ferro-manganiferous concretions occur. It is remarkable that these small pellets stand out like hard blisters on a weathered surface. They were predominant for about four feet from the surface and then they decreased. The size of these pellets rarely exceeds one-fifth of an inch. These concretions are not only rounded in shape but are irregularly elongated also. A little lower down the brownish

black concretions attain a bigger size, varying from half an inch to one inch, but their number becomes smaller.

Kankar Concretions :—The shape of these concretions is very fantastic indeed. Usually, it occurs in irregular lumps, but occasionally it has been observed to occur as small rounded nodules. Sometimes these concretions are flat, while others are elongated and branching and sometimes about a foot in length.

It is usually observed that the stratum of *kankar* thins out laterally and it occurs in patches in the form of lenticular deposits.

A specimen of *kankar* from the Benares Hindu University area was analysed by Mr. R. C. Misra with the following results :—

Silica	..	34·01
Carbonate of lime	..	56·12
Alumina and Ferric Oxide	..	9·20
Magnesia	..	0·76
Water and organic matter	..	..
Total	..	100.09

Newer Alluvium :—The Newer alluvium is confined to terraces and flood plains of the rivers and their tributaries. It is composed chiefly of sand, silt, mud and clay. In the bed of the channel, usually sand and sandy loam occur but on the adjoining flat ground fine loam to clayey loam are to be observed. Below this, sand and clay were found to alternate in a water well section near the Ganges near Benares and very little *kankar* was observed.

Rainfall :—The great variation in the amount of rainfall over these plains has been discussed above. A reference to the rainfall map of India (Fig. 15) may be made again. As stated above, Sind Rajputana and the Western

Punjab remain practically dry, except for a few seasonal showers and the rainfall sometimes hardly exceeds 5 inches *per annum*. It then gradually increases as one proceeds to the east. In the United Provinces it varies from 24 to 40 inches, while it reaches 70 inches at the head of Bengal. Cherrapunji receives the maximum amount of rainfall in the whole world.

Dependent upon rainfall, there would be a great variation in the amount of leaching of the soils which is an important factor in determining their nature. They are generally, light-coloured, loamy soils with a high degree of fertility, but they show a difference in density, texture, porosity, moisture-content, etc.

The soils of the Indo-Gangetic plains are relatively rich in lime, magnesia and potassium. The occurrence of *kankar*, an impure carbonate of lime, has been referred to above.

In the region drained by the Brahmaputra, which receives heavy rainfall, a greater leaching of the soils occurs and the soils are poor in lime, magnesia and potash and are mainly sandy.

Thus the soils of this area have been classified into :—

(a) The Indus alluvium.

(b) The Ganges alluvium.

(c) The Brahmaputra alluvium.

There is some difference in the chemical composition of these alluvia, but, as noted already, dependent upon rainfall there is a considerable difference in the leaching of these soils. The soils of the Indus belong to arid and semi-arid climate, while those of the Brahmaputra fall in per humid area.

Soils of the Punjab :—The soils of the Punjab have received greater attention. The mechanical analyses of the surface soils from many parts of the Punjab reveal that they are clayey loams which are very well-suited for cultivation. They can retain adequate moisture and being soft are not difficult to work. With irrigation and suitable manuring they may yield any type of crop.

Chemical Composition :—Some analyses of these average soils were carried out by Messrs Bagchi and Agarwal under the guidance of the author and they are reproduced below. After proper sampling, bulk analyses of these soils were made after fusing them with fusion mixture.

	I	II	III	IV
Silica ..	63·40	64·98	70·12	76·79
Alumina ..	14·48	12·69	9·96	6·35
Ferric oxide ..	3·60	1·32	11.61	8·52
Ferrous oxide ..	2·34	3·97	0·19	....
Manganese dioxide ..	0·16	0·05	0·05	0·02
Lime ..	1·41	2·98	2·41	0·70
Magnesia ..	2·10	1·99	0·61	0·39
Titania ..	1·00	0·58	0·12	0·24
Potash ..	1·43	1·46	0·15	0·12
Soda ..	2·14	2·65	0·06	0·19
Loss on ignition ..	8·01	7·46	4·75	6·40
	100·07	100·13	100·03	99·72

I. Clay, Benares Hindu University near the new Morvi Hostel. This is locally called *Talai* soil. The site may have been occupied by a *talao* or a tank before. Analyst, Y. K. Agarwal.

II. Loam, Benares Hindu University. Analyst, Y. K. Agarwal.

III. Clay, Benares district. This soil is locally called *Karail*. Analyst, T.C. Bagchi.

IV. Loam, Benares district. Analyst, T. C. Bagchi.

These analyses have revealed some very interesting facts. As to be expected, loams contain a higher percentage of silica than the clays. In contrast to this, the loams contain a lower percentage of alumina than the clays. The percentage of iron sesquioxide is also higher in the loams than in the clays, while magnesia is lower in the loams than in the clays. It is noteworthy that the percentage of both potash and soda is lower in the loams than in the clays. It is also to be observed that the proportion of alumina, magnesia, manganese, potash and soda decreases with the increase in silica in loams.

Below are also reproduced some of the partial analyses of the soils of the Indo-Gangetic plains.

	I	II
Insoluble matter	81·54	88·08
Alumina	4·36	4·38
Ferric oxide	5·11	3·10
Lime	0·98	0·47
Magnesia	1·72	0·32
Manganese sesquioxide	0·11	....
Potash	0·54	0·64
Soda	0·25	0·09
Phosphorus pentoxide	0·14	0·08
Sulphur trioxide	0·02	0·05
Carbon dioxide	0·45	0·37
Water and organic matter.. ..	4·78	2·42
Total	100·00	100·00

I. Loamy soil, Changa Manga, the Punjab. Analyst, Mr. Mann.

II. Sandy loam, Lower Ganges Doab. Analyst, Mr. Mann.

These analyses reveal the same facts as stated above.

However, these alluvial soils are generally low in nitrogen but alkalies, both potash and soda, and phosphoric acid are sufficient. The lime, magnesia and iron oxide are very variable. The capacity for base exchange of these soils is satisfactory and the clay-factor is high. Their physical properties, like porosity, texture, etc., generally tend to provide for good drainage and are favourable for purposes of cultivation, with the result that the soil have been cultivated from the earliest times, and yet are sustaining greatest pressure on land in India. There is no doubt that with suitable manuring the yield from these soils can be considerably improved.

Deltaic Soils :—The deltaic soils of the Indus and the Ganges are more or less a continuation of the alluvial soils of the valleys, but are generally richer in humus content. Some parts of these regions are, however, very humid, almost water-logged, owing to repeatedly bifurcating channels. During floods, fertile silt is deposited. These lands are very suited to paddy cultivation and also jute, particularly in the delta of the Ganges and the adjoining regions.

Likewise, the Bhabar and the Terai soils, lying immediately below the Himalayan region, need not be omitted. The Bhabar slopes are composed of gravel and shingle which support dense sal forests, while the Terai region represents marshy soils covered with tall grass. In the Gorakhpur and the adjoining districts, this area has been brought under sugar-cane cultivation. The district of Gorakhpur alone supports more than 20 major sugar factories and has been styled as "the Java of India". There is hardly a railway station in this district, where one or even two sugar factories do not exist.

Alkali Soils

Some lands in the northern part of the United Provinces, parts of Bihar, the Punjab and Rajputana have been rendered barren owing to the impregnation of the saline and alkaline compounds in the upper portion of the land. These salts are called *reh* in the United Provinces and Bihar and *kallar* in the Punjab and the lands are styled as *usar* or *kallar* lands. The extent of these *usar* lands is not exactly known, but they represent about 300 square miles of *kallar* lands in the Punjab. Likewise, in the Western United Provinces, they occupy large areas in the districts of Saharanpur, Muttra, Aligarh, etc., and the total *usar* land area in the U.P. has been estimated at more than 5 million acres. Large areas are spoilt by sea water in Bengal, Gujarat and in the Presidencies of Bombay and Madras. It is considered that due to excessive temperatures and lack of moisture in many parts of India, the extent of *usar* land is on the increase in India.

Alkaline Salts:—Generally these salts comprise carbonate and sulphate of sodium with associated sodium chloride and sodium bicarbonate. The soils, which contain excess of sodium chloride and sodium sulphate, represent saline soils, while alkaline soils contain excess of sodium carbonate. They have an alkaline action and it is the carbonate, which chiefly renders these soils sterile.

Origin of the Salts:—The Himalayan rivers and their tributaries transport salts in solution which comprise carbonates and sulphates of calcium and magnesium with some associated sodium chloride. These salts percolate into the subsoil of the Indo-Gangetic plains. In those areas, which enjoy an arid climate and have no proper surface drainage, these salts keep on accumulating by leaching from the neighbouring regions. During the dry season, the soluble salts are sucked up in solution by

capillary action to the surface and are deposited there in the form of a white efflorescence. Thus extensive areas of land, which have been impregnated with these salts, have been lost to agriculture.

The canal irrigation has also been responsible for the development of such lands. The canal water contains these soluble salts, which, owing to seepage and water-logging, are deposited in the adjoining lands. This irrigation also raises underground water-level and considerable evaporation takes place with the deposition of these salts, which render the soil useless for agriculture.

Characteristics of Alkali Soils:—These soils are very alkaline in character, and their pH value reaches 10.8. These soils are deficient in calcium salts. The nitrogen content is also low. The soil becomes highly impervious. As the alkali soils do not support much vegetation, bacterial activity and organic matter are practically absent.

Reclamation of Alkali (Usar) Lands:—Reclamation of *usar* lands is a subject of great importance and has received the attention of many research workers. The procedure is to convert the sodium clay to a calcium one, and this was brought about by Hilgard and others in reclaiming the alkali soils in the Western States of the U.S.A. by adding about 12 tons of gypsum ($CaSO_4.2H_2O$) to the soil per acre and flooding the soil with water. Sodium sulphate was formed which could be dissolved away and the sodium clay was replaced by the calcium one. This treatment has also been used in relaiming large tracts of land in Russia.

Powdered sulphur at the rate of 20 to 30 cwt. per acre has also been found beneficial in the reclamation of alkaline soils. By this method sulphur is converted into

sulphuric acid, which destroys the alkali present in the soil.

Alkali soils in Hungary have been reclaimed by de'Sigmond by reducing the evaporation from the surface by growing lucerne. It requires large amounts of moisture and dries up the soil. This decreases the upward movement of salts.

In India it has been attempted to reclaim the *kallar* (alkaline) soil in the Montgomary district, etc., by adding a mixture of gypsum and calcium chloride. This method takes four years in the process of reclamation.

Another method used in the reclamation of alkaline lands is by the application of molasses. This process, which has been evolved by the researches of Dr. N. R. Dhar and his co-workers, has been successfully applied in Mysore, and in Allahabad and Cawnpore by adding one ton of molasses per acre. Thus good crops have been produced on lands which were absolutely sterile and yielded no vegetation at all. Molasses possesses the following percentage chemical composition :—

Carbohydrates	60—70
Potash	4—5
Lime	2—1
Phosphoric acid	0·5
Iron oxide Aluminium oxide }	0·5
Combined nitrogen	0·65
Water	balance

Molasses is definitely acidic in character. Thus the acids present in the so'l and those produced on decomposition and partial oxidation can neutralise the alkali of these soils. The carbonic acid produced on the decomposition and oxidation of the carbohydrates can change

the carbonate of sodium into bicarbonate. By the escape of carbonic acid from the soil, to which molasses has been applied, it is rendered porous with the improvement of its tilth. The moisture-content of the molassed soils is also higher. By the addition of lime, along with molasses, the sodium soil is converted into a calcium one. This also increases the permeability of the soil. It has been shown that molasses can reclaim the alkali soils better than either gypsum or powdered sulphur. In the latter case there is a loss of nitrogen, while molasses adds nitrogen to the soil and it also reacts much quicker. It is stated that the treatment with gypsum or powdered sulphur takes four years for reclamation, while molasses acts it in two to six months.

Likewise, press mud of sugar factories, containing large proportions of carbohydrates and calcium salts, have a useful effect on the alkali soil. It is suggested that the soil should be ploughed before applying molasses. After the addition of molasses, it should be dug or turned over once a month. It is noteworthy that by this treatment, deficiency of nitrogen, calcium, organic matter, etc., of an alkaline soil is removed and the improvement is permanent. Of course, this method is also very cheap, particularly in regions where sugar factories are located. The author has observed that in some areas, the management of sugar factories have no economic use for the molasses. In some cases it hardly fetches a few annas per maund.

It has also been suggested that oilcakes can also be utilised successfully in the reclamation of alkali soils.

Desert Soils

Rajputana, part of Sind, Baluchistan and the Southern Punjab form the Indian desert. The region is covered by a mantle of largely wind-borne sand. Owing to desertic character of the region, the soil has not attained any

mature stage of development. The region lies on the path of the monsoon winds, but owing to its physiographical position, it receives only a very scanty rainfall. The sand of this region is not formed by the disintegration of the underlying rocks, but a major portion has been deposited by winds blowing from the coastal region and the Indus valley. Owing to this sandy deposit, a great portion is sterile, but in places, some agriculture is carried on, particularly where there is some water available from deep wells for irrigation.

On the coast of Orissa and in some parts of Madras sand-dunes occur. These lands are thus rendered waste.

Himalayan Soils

The soils of the Himalayas are important for various purposes. In places, terraced cultivation is practised on them but it is these soils which support some of the important forests of India. References to the geology, climate, and making of the Himalayas have been made already in appropriate places. As stated above, these mountains were upheaved only during the Tertiary times and the mountain-building movements have not yet even ceased. Above 20,000 feet above sea level, they are permanently snow-clad. On the whole the Himalayan soils are young and immature and they have depth, if any, either in the valleys or on gently inclined hill-sides. The southern slopes facing the plains of India are steeper than the northern slopes which are thus more favourable for the accumulation of soil. The soils of the Himalayas, however, are very variable, depending upon the geology, climate including rainfall, relief, aspect, etc.

Tertiary Soils:—Beginning with the Siwaliks, which form the foot-hills, practically all along the mountains, they yield usually light sandy soils which are somewhat shallow, porous and contain little humus. Similarly, the Murree rocks, as exposed in the Western Himalaya are

composed predominantly of sandstones and yield soils only slightly superior to those of the Siwaliks. But in some of the valleys of these hills, *e.g.*, Dehra Dun, Kashmir, etc., the alluvial soils are fertile. In the Lower Tertiaries, clayey soils are predominant, which are certainly more fertile and can retain moisture much better.

Tea Soils :—The soils of the Middle Himalayan zone are the most productive. Some of the soils of the Eastern and Central Himalayas, with good rainfall and rich in humus, are very suitable for the cultivation of tea, *e.g.*, in Assam, Darjeeling area, the Duars, the Doon valley and the Kangra district of the Punjab. Two essential factors for a good tea soil are good rainfall and good drainage otherwise any soil from stiffest clay to lightest loam has proved suitable. The best soil for tea cultivation is a medium or a light loam. Most successful tea soils are low in lime-content and are acid in character.

Soils of the Older Rocks :—The soils, derived from the older rocks and composed mainly of schists, shales and slates are somewhat clayey which have a much better retentive capacity for moisture. These make good arable soils. But it may be noted that quartzites, *viz.*, the Muth quartzites, or those associated with other formations, being composed mainly of quartz, yield only light infertile soils. Being hard, cliffs, crags and sharp bare ridges are very common. The author observed a very vivid example while working in the Bhim Tal area of the Naini Tal district. In this neighbourhood two rocks, *viz.*, the trap and the quartzites were observed, and it is noteworthy that every inch of the trap soil was under cultivation, and in fact, one could almost map the extent of the trap by the limit of cultivation, but the adjoining quartzites remain barren, sometime in spite of the best efforts of the cultivator.

The Russian pedologists have claimed that two soils,

under the influence of climate, begin to lose the effect of the parent-rock and tend to become similar. These two rocks have existed together at least since the Palæozoic times but yet they are as different in character as when they first came into being. The author has observed several other similar instances.

Limestone and Dolomitic Soils:—In places in the Himalayas, *e.g.*, Mussoorie, Chakrata-Deoban, Naini Tal area, etc., particularly where the geology is composed of the Krol formation, large areas are formed of limestone and dolomitic rocks. These rocks are soluble and being somewhat pure, little soil accumulates, particularly on steep slopes and only bare greyish or dark grey crags, cliffs or knife-backed ridges are to be seen. Only in suitable places in the valleys, any residual or detrital soil may accumulate, where cultivation of rice, etc., may be carried on. The residual soil capping the dolomites of the Naini Tal area was observed to be reddish-brown in colour, which however, becomes lighter in tint and also hard when dry. On moistening the soil, it emits a characteristic clayey odour. In this case the residual soil has been concentrated in clayey and ferruginous material. The valley of Sahasradhara, which is easily accessible and only a short distance from Dehra Dun, provides an excellent field for the study of such soils.

Igneous Soils:—In the Himalayas, intrusions of several kinds of igneous rocks occur, *e.g.*, granites, dolerites, etc. at various places. The granites form only light sandy soils, while dolerites yield good fertile soils. Likewise, extensive areas are occupied by trap rocks, *e.g.*, the Panjal trap, Bhim Tal trap, etc. These rocks, as noted already, yield fertile soils, and particularly when the slopes are not unfavourable for the accumulation of soil, every inch of the ground is suitable for purposes of agriculture.

CHAPTER XVIII

SOIL EROSION

Soil is the real wealth of the cultivator. The more it is preserved, the better will be his fate. But the erosion of the soil is assuming alarming proportions in India and this is indeed one of the major problems confronting this country. The exact extent of this soil erosion is difficult to estimate but it has seriously affected about 150 million acres of land devoted to agriculture. In the United Provinces alone ravine lands occupy about eight million acres. Utmost attempts have therefore to be made to prevent its erosion. The forests or vegetation, by providing a protective and binding covering, play a very important rôle in checking the erosion of the soil. We shall study the importance of vegetation a little later.

The Soil :—It represents the top portion, *i.e.*, the uppermost layer of the earth's crust, which provides the humus, organic and mineral matter which are so vital to plant growth. If the soil is removed by erosion, the above constituents are lost and thus the fertility of the land may be greatly reduced, or it may be rendered entirely sterile. It will thus result in the lower yield of crops from the land. Once the soil is lost, it will indeed take a long time to develop again, as the soil-forming processes are very slow. It is, therefore, imperative that every care should be taken not to lose the soil by erosion.

Lands Undergoing Soil Erosion :—The menace of soil erosion is common in many parts of India. Beginning from the north, very notable and spectacular instances of soil erosion are to be found in the Hazara district of the N.W.F.P. and the Campbellpur, Jhelum, Hoshiarpur and

Ambala districts of the Punjab. In the Hazara district, forests, which existed about 75 years ago, disappeared gradually, in order to find fresh land for cultivation and also as a result of overgrazing, lopping and felling of timber. The Hoshiarpur district provides a very glaring example how, by ravine erosion, land has been lost to agriculture. In 1852, 75 square miles of land was occupied by *chos* or seasonal torrents, but about 85 years later, this area had increased ten times. In fact, all along the foothills of the Himalayas, this soil erosion is proceeding very rapidly.

In Assam and Bengal, river erosion and deposition of sand are very noteworthy. Other parts, where soil erosion is taking place, include the area south of the Jumna, Baluchistan, Bihar, Central India and parts of the Bombay and Madras Presidencies.

A considerable amount of soil, which once belonged to the above fertile lands, now unfortunately lies at the bottom of the sea.

Rate of Erosion :—The rate of soil erosion is determined by several factors. It depends upon the amount of the slope. On a steeper slope, which may be even unstable, the soil is washed away much more rapidly than on a gentler slope. On steep slopes, landslips and landslides, due to percolation of water and instability of slopes owing to gravity, will be common and frequent. The second important factor is the character of rainfall. The heavier the rainfall the greater the erosion. Rain from gentle showers generally tends to soak into the soil and proves beneficial. But if the showers are heavy and torrential, the erosion will be greatly enhanced. Sometimes there may be as much as several inches of rainfall in 24 hours. This rain mostly runs off and carries with it the soil. In case of heavier and torrential showers, the velocity of running water is augmented, which greatly increases its trans-

porting power. For instance, if the velocity is doubled, its carrying capacity is increased to the sixth power of velocity, and the transporting power is increased about 64 times. With the increased velocity the water can transport larger-sized material.

The silt carried by water also aids in soil erosion. By abrasion or friction it increases both the lateral and vertical erosion, *i.e.*, both on the sides and the bed of the stream.

The rate of erosion also depends upon the nature of the soil. Loose unconsolidated material will be washed away very readily. Lateritic clays, for instance, are more resistant then soft plastic clays. In the case of soft rocks like clays, sand-rock, shales, phyllites, etc., particular care should be taken that the binding and protective cover of vegetation is not destroyed.

Types of Soil Erosion :—The soil is chiefly eroded in two ways. One is called the sheet erosion, where the soil is eroded as a thin layer from the hill-slopes. This particularly happens when the sloping land is not properly terraced into flat fields with proper embankments. It is noteworthy that the sheet erosion will take place, wherever the valuable and useful cover of vegetation has been destroyed by felling of timber, over-grazing and burning.

The second type of erosions is the gully erosion. The water forms small rivulets and these, by washing away the soil, form chasms or gullies. First, there is the main ravine, and then side rivulets form lateral gullies. This phenomenon, once started, and if not checked, goes on extending and ultimately the whole country is converted into a 'badland' topography. This can take place both on sloping as well as on almost flat ground. Such sites, as noted already, are common in the Punjab, U.P., and Bihar. The author, while travelling in the United

Provinces, *e.g.*, near Agra and Etawah, or between Benares and Lucknow, has observed such gully erosion on the edges of the arable land. It is noteworthy that this process works by head erosion and extends gradually into the interior of the cultivated land. In the hilly region, particularly in the outer Siwalik hills, where the country is generally composed of soft sand-rock, by water erosion during the wet season, deep valleys and *khuds* are formed. This phenomenon is commonly observed in the *Kandi* or the Siwalik hills of the Jammoo State, the Hoshiarpur district of the Punjab and other regions of the Siwaliks which have been denuded of their forest and grass vegetation. By this gully erosion, the land, which once formed fertile fields, is converted into waste lands.

Importance of Vegetation

The importance of vegetation in checking this soil erosion cannot be over-emphasized. It has been noted above that the vegetation forms a binding and protective covering. The vegetation in the catchment areas of rivers helps to store the rain water in its roots, which subsequently sinks into the soil. This water in the dry season replenishes the waters of the streams and rivers, which in the lower regions is used for purposes of irrigation, and development of hydro-electric power, or forms the water supply of the country from wells. When rain falls in heavy showers, the flow of the surface water is checked by the vegetation and the fury of the floods is considerably abated.

But deforestation or destruction of forests and undergrowth has serious consequences. The water flows away unchecked to cause severe floods in the lower regions. The rushing water also removes whatever comes in its way including the valuable surface soil, thus exposing or leaving behind the subsoil or the rocky ground from underneath.

The subject is very important since deforestation in one province might have serious consequences in the adjoining one. It must, therefore, be considered and treated on an all-India basis.

Causes of Soil Erosion :—Anything that tends to destroy vegetation is assisting in the erosion of soil. Animals, by over-grazing, form one of the important causes of the destruction of vegetation; it may be in the pasture-lands, or it may be in the forests. The climate of India is such that the wet season is followed by a long drought, when grasses do not grow, while the animals have to subsist. They thus remove whatever vegetation is there. Further, to feed some of them, the human agency scrapes whatever grass is there on the soil. The bare soil, thus produced, is no longer able to withstand the impact of the showers of the succeeding monsoon, resulting in a maximum of soil erosion.

Likewise, as a result of the increase of pressure of population on soil, the forests were gradually cut down to find fresh land for cultivation. This menace was on the increase until the Government had to create Reserved Forests, where grazing, felling of timbers, etc., had to be regulated according to plan. This stopped also shifting cultivation. Unfortunately, the forests of India occupy only a very small percentage of the total land surface, particularly when compared to some other advanced countries of the world.

Shifting Cultivation :—This shifting cultivation is a very common, nefarious practice in some of the hills of Assam and Bengal, where every year a fresh patch of the forest is destroyed and burnt to find land for cultivation. This virgin soil with the ashes of burnt vegetation must prove fertile, but this is a very dangerous practice, as it

evidently helps in accelerating erosion, and sometimes only bare rock is left with obvious results. Next year a new patch is chosen to repeat the same proccdure. Similarly, the village forests have gradually disappeared, thus again exposing the land to the full fury of the agents of denudation.

Human Action :—Faulty methods of cultivation are also responsible for bringing about the rapid erosion of soil. Potato cultivation, where the rows are aligned along the slope rather than across it, are ideal for causing extremely rapid erosion of the soil. It has been estimated that thus about 150 to 200 tons of soil to an acre are lost *per annum*. This loss means an inch of top soil every year. Similarly the cultivation of the unstable slopes results in a tremendous erosion of the soil.

Effects of Soil Erosion

The importance of the soil to the cultivator, or in fact to the whole society, has been referred to above. Its erosion indeed results in serious consequences. It may cause scarcity or famines, which may not occur owing to failure of rains. But the shallowness of soil, as a result of soil erosion, may be an important factor. A shallow soil cannot nourish the crops properly and it cannot also store sufficient water for them. This will result in lower or no yield of crops, which will mean undernourished human beings with a lower standard of living. Poor pastures will support only under-fed animals.

Floods :—By the destruction of vegetation and consequent soil-erosion, floods are caused and their severity and frequency is greatly increased. In the provinces of Assam, Bengal, Orissa and the United Provinces, these floods effect a very serious havoc by causing considerable loss of life, both human and animal, property and crops. In

some cases the peasant loses everything and is rendered destitute. In 1938, in the East United Provinces alone, the floods caused havoc in 8,000 villages, affecting nearly one million people or more.

These floods also cause great damage to communications by causing breaches in railways and roads. They may also damage or burst dams or head-works of canals, etc.

In case the vegetation in the headwaters of the rivers has not been interfered with, all the water would not be released at once for these floods, and consequently their fury will be greatly checked.

Lower Rainfall:—When the forests are destroyed, the land becomes directly heated, and the hot air rises. It dissipates the clouds without dropping their moisture. Thus the climate becomes drier than before. Rajputana furnishes a very notable example, where land has been desiccated as a consequence of the destruction of vegetation.

Falling of Subsoil Water:—In some parts, particularly in the Hoshiarpur and Jullundur districts, there has been a marked lowering of the subsoil water. The cause is obvious. The removal of the sediments by water results in the clogging of the soil, which prevents percolation. Furthermore, by soil erosion, the bare rock is exposed which allows the water to drain off almost completely with the result that very little water soaks into the ground. When percolation or seepage, as a result of deforestation, is reduced to a minimum, the gound water level is bound to fall. With the lowering of this water-level the crops do not receive adequate moisture, particularly in years of drought.

Erosion of Sand:—When the forests are removed, sand is freely eroded from the Siwalik hills by the torrents in flood. This is deposited lower down in the plains, where

it tends to spoil the agricultural land. The Jullundur *doab* is a very good example of such a deposition of sand.

Similarly, by the same process, the sand is deposited in water reservoirs, etc., thus resulting in their silting and shallowing, with the consequence that the quantity of water available decreases.

Extension of Arid Conditions and Æolian Action :— It has been observed that arid conditions are already extending to the south-western districts of the United Provinces, *viz.*, the Muttra, Aligarh, Agra, Etawah, Hamirpur, etc. Wind picks up the sand of the fields and transports them to other areas, where it is deposited in the form of sand-dunes. Besides the covering of the fields by these shifting sand-dunes in Rajputana, the author has observed them to occupy land, either partially or wholly, even in some of the districts of the United Provinces. They were observed in the Budaun district and also in the Moradabad district, for instance, between Moradabad and Amroha. Likewise, the coastal sand is carried inwards, with obvious results, but this is checked by casuarina plantations, groves of coconuts palms, etc., in Peninsular India.

Conservation of Soil

Having discussed the causes and effects of soil erosion, we now consider the remedies. These, as already noted, lie in the restortation of the protective and binding cover of vegetation, and this process is called afforestation. Second method consists in terracing and ridging the fields in the hilly regions as already practised in a number of areas, *e.g.*, in the neighbourhood of Naini Tal, in British Garhwal, Darjeeling, etc. The third method lies in making suitable embankments of the fields. These remedies help to conserve moisture and prevent soil erosion. At present the various Provincial Governments are engaged in the

study of the problem of soil erosion and are considering the methods by which to eradicate this very serious menace. In Chapter I, India has been divided into the main physical regions. Each of these regions is considered in some detail below.

The Himalayan Region

Commencing from the north, there is the Himalayan region which has been described in Chapter II. Its climate has also been discussed in Chapter XIII. The foothills of this lofty chain comprise the Siwaliks followed by a number of high ranges. It has been noted already that the rainfall in the Eastern Himalayas is considerably higher than in the west, which, in fact, forms one of the very arid regions of India. The Eastern Himalayan region is well-forested; in fact, the area under forests represents about 40 per cent. of the total land, but unfortunately *jhumming* or shifting cultivation is practised on a large scale with the consequence that the soil is eroded away rapidly leaving behind the bare rock. It is also noteworthy that the heavy rainfall of the region is very conducive to the erosion of soil. The Chief Engineer of Assam in his "Note on Floods in the Surma Valley, Assam—their causes and remedies, 1922" made a special reference to the detrimental effect upon streams of deforestation and shifting cultivation in the hills. He also added that the engineers of the Assam-Bengal Railway attributed the destruction of the hill section of their line to the same cause. He emphasised that forests at the headwaters of the rivers would, if preserved, retain the rain and prevent disastrous floods and also store water for the dry season; so that the deforestation at the headwaters of streams and along lines of communication should be strictly regulated or prohibited, as the vested interests in the hills are but small compared with the vast interests

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Plate X

Fig. 1.—Showing a 'badland' topography near Brahmdih village, near Ranchi, Bihar. —*Photo: H. L. Chhibber.*

Fig. 2.—Properly terraced cultivation fields, Naini Tal District, Kumaun Himalaya, U.P. —*Photo: H. L. Chhibber.*

at stake in the rich plains below. It has, therefore, been recommended that this type of cultivation in the hills by the destruction of forests must cease in entirety and it should be replaced by terraced fields with proper embankments.

Proceeding westwards, the conditions are better in the U.P. Himalayas, where the forests have not been ruthlessly destroyed from the Siwalik hills and the higher Himalayan regions. In the Kumaun Himalayas comprising the districts of Naini Tal, Almora and British Garhwal, terraced fields with suitable embankments are to be observed.

The Western Himalaya:—The conditions in the Western Himalaya are absolutely different. Although the winter has a bracing climate, but the long dry season coupled with heavy grazing makes the vegetation lose its hold on the soil. The forests have been cut down with the obvious result that the lands, which were cultivated within the present human memory, have become barren as a result of soil erosion. Where grazing is not allowed, *Sabai* and *bhabar* grasses flourish, which are in great demand as a raw material for the paper mills.

It is noteworthy that village forests have been created, which are now being managed by co-operative forest societies. This has brought about considerable improvement of soil conditions.

The Indo-Gangetic Plains

South of the Himalayas, the irrigated plains of the Ganges constitute one of the most densely populated regions of the world. But these lands are flooded owing to heavy rainfall in the Himalayan region and destruction of vegetation.

The Punjab is the land of the five rivers, from which 'the best canal system in the world' has been fashioned. The canals irrigate the wheat and cotton lands of the Punjab and Sind. But floods often damage the head-works of the canals and there is also the silting of the bed of the rivers, which might cause their meandering. The canals are also being silted by the material transported in suspension. As a result of afforestation in the hills, the frequency and severity of the floods will be greatly diminished.

Peninsular India

The geology, the climate and the drainage of this region have been described above. The region is mostly composed of hard crystalline rocks, which decompose very gradually with the result that the soil is usually very thin. In places, bare granitic and gneissic hills rise above the general level of the surrounding country. The soil on the Deccan trap region, which commonly forms a flat plateau-like country, is somewhat thick, as also in the valleys. But there has been a considerable sheet erosion, wherever the vegetation has been destroyed.

The forests of the Deccan vary in character from dense evergreen forests of the Western Ghats to the thorny and scrub forests of Central India. Some of the important forests and those of some of the catchments areas were reserved by the Government and in these cases there is practically no erosion of the soil. But some minor forests were allowed for the use of the local population, but in these cases there is no effective check and grazing is heavy and the trees are lopped for fodder. These minor forests, therefore, present only a very partial control on the destruction of vegetation and hence on soil erosion. In some cases, forests have entirely disappeared leaving behind only stony wastes. It is suggested that the co-operative

management of the village forests by the village *panchayats* under expert guidance is greatly desirable.

The pastures in this region thrive well during and a little after the rainy season, but during the long dry season these are greatly impoverished and thus provide little protection from soil erosion. In this case, the decrease in the incidence of grazing by keeping only a smaller number of superior and fit cattle is recommended. Stall feeding and the use of the portion of pastures in rotation will not only help in the prevention of soil erosion, but also in the production of better grasses.

Usually, the irrigated lands, *e.g.*, the rice, wheat, cotton and sugar fields are well protected by bunds, so that no water is wasted, but the unirrigated lands are not properly maintained and protected with the result that, as a result of sheet erosion, the soil is gradually getting shallower and consequently poorer.

Conclusion

The need for the conservation of soil in a dominantly agricultural country cannot be over-emphasized. Nothing should be done which will accelerate the erosion of the soil. Vegetation in the form of forest and undergrowth must not be destroyed recklessly, particularly in the headwaters of rivers, otherwise devastating floods, the erosion of soil and lowering of ground water-level bring about the desiccation of the region will be the consequences. Early afforestation must be resorted to, where the forests in such areas have been destroyed. The sloping land should be properly terraced and ridged for purposes of cultivation. Faulty methods of agriculture, which would bring about rapid removal of soil, must be scrupulously avoided. Unstable steep slopes must not be touched for purposes of cultivation.

CHAPTER XIX

FERTILISERS AND MANURES*

In a country like India, where a very large majority of the population still depends upon agriculture, importance of the knowledge of mineral fertilizers and manures cannot be over-emphasized. By cultivation of crops the soil loses some of the plant nutrients, and if repeated continuously for sometime, and not replenished by manures, will result in the exhaustion of the soil and the lowering of the yield of crops. In fact no account of soils would be complete without a reference to them. Unfortunately, a great bulk of the rural population of India is somewhat poor with small holdings and is slow to take advantage of new and improved methods of agriculture. But in this connection it may be noted that big *Zemindars* and *Talukdars* with large estates can help themselves and their peasants. They still largely depend upon cow-dung compost, but even the cow-dung is largely burnt as fuel. The author feels strongly on this point, and he considers that this wasteful use of cow-dung should be stopped by legislation. It is, therefore, the duty of educated young men to take the latest ideas to the country so that it benefits by the application of the modern methods of scientific thought and research. In order to enjoy proper benefit from fertilizers, a more detailed knowledge of our soils, than what is known at present, is absolutely necessary. Knowing the actual deficiency of the different soils, proper treatment can be given to them. In fact, the main impediment in Indian agriculture is the lack of sufficient manure, which is responsible for low yields.

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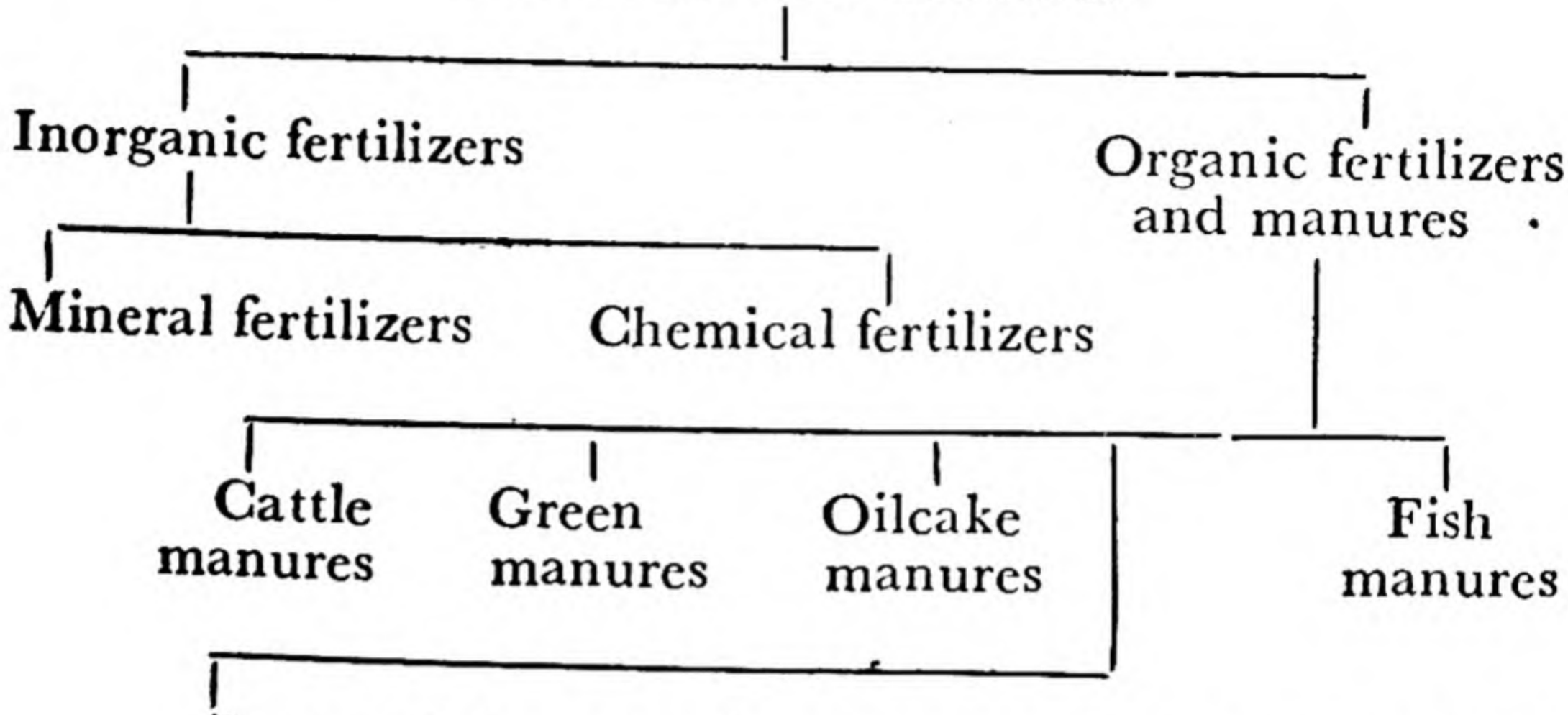
*The author wished to deal with Mineral Fertilizers only, but for purposes of completion, other fertilizers and manures have been included.

Classification :—The following scheme of classification of fertilizers and manures is suggested by the author.



Both the mineral and chemical fertilizers may be further sub-divided into :—

(*a*) Phosphatic fertilizers.

(*b*) Nitrogenous ,,

(*c*) Potassic ,,

(*d*) Calcareous ,,

Mineral and Chemical Fertilizers

It is noteworthy that the soil requires four mineral constituents, *viz.*, phosphorus, potassium, nitrogen and calcium for the proper growth of plants. Iron and manganese are also required in small amounts, particularly for resisting disease. The stunted growth of the Japanese is attributed to the deficiency of lime in their soils. Again, the Jersey cow, which has a low-lime soil in her native habitat, attains a marked increase in the bone structure, when transported to high-lime environment.

Mineral Phosphatic Deposits

Phosphorus is one of the most useful constituents needed for plant growth. The primary source of phosphorus is the mineral apatite, which is chloro or fluoro-phosphate of calcium. It is an important constituent of pegmatites, which are found in several parts of India. The mineral also occurs as veins and lenticles in igneous and metamorphic rocks.

Bihar :—It is associated with the mica pegmatites occurring in the districts of Monghyr, Gaya and Hazaribagh in Bihar. This mineral is known to have been present in the dumps of certain mines in the Kodarma forest in the Hazaribagh district, but a later examination of the mica mines has not given encouraging results.

Apatite is also an important accessory mineral, occurring in the mica-peridotites cutting the coalfields of Bengal and Bihar. Sometimes the mineral may be present up to 10 to 11 per cent. Although the total amount of apatite present in these dykes may be large, but it is not certain whether its recovery will be an economic proposition.

Singhbhum District :—Massive apatite also occurs in lenticular aggregates in the Dharwar rocks of the Dalbhum and Singhbhum districts. The belt extends for about 40 miles from Dhadkidih in the Seraikela State to Khejurdari in the Dalbhum district and runs parallel to both the Bengal Nagpur Railway and the Subarnarekha river. It is also known to extend into the Mayurbhanj State. The veins and lenticles range in extent from anything to 50 feet in thickness and with a length of 200-300 feet. The average percentage of phosphoric pentoxide ranges from 20-25 before magnetic separation. The total reserves of apatite

in this belt have been estimated to be 700,000 tons, while the reserves of individual areas are as follows :—

(1) Nandup area	..	250,000 tons
(2) Patharghara area	..	250,000 tons
(3) Badia-Kanyaluka-Sungri area	..	200,000 tons

Working of the Singhbhum deposits was commenced in 1918, but it gradually decreased after about 10 years, and the total output during this period is given as 28,000 tons of apatite-rock.

Bombay :—Apatite-rich rocks also occur at Jothvad in Narukot State, in which apatite may form 30 per cent. of the total. These deposits require further attention with a view to the possibility of concentrating apatite after crushing.

Madras :—Apatite also occurs in the Kodurite rocks in the Madras district and is found in appreciable quantity in some of the mines.

Sedimentary Phosphatic Deposits

Rock phosphates are of sedimentary origin and some of the marine organisms contain appreciable proportions of phosphorus. Limestone is easily replaced by phosphates and thus phosphatic limestones are formed. Some of the Lower Vindhyan limestones contain small quantities of associated phosphates. Some of the specimens of *kankar* also contain very small percentage of phosphorus.

Trichinopoly District :—Important deposits of rock phosphates are found as nodules in the clays in the Trichinopoly district of Madras. As noted already, variously-shaped nodules occur in the Utatur stage of the Cretaceous rocks. They occur in an area of 11 or 12 square miles in the neighbourhood, and the estimated reserves are about 800,000 tons to a depth of 200 feet. The chemical composition of these nodules has already been given in Chapter XV.

A few attempts were made to use the powdered material as a manure in the raw state in coffee and tea plantations in Southern India and Ceylon. The mineral is flour-apatite which has very low solubility in the soil. The results were disappointing in comparison to the use of superphosphate and ammonium phosphate.

Dandot, Punjab :—Phosphatic nodules are also found in the shales which overlie the Eocene coal in the eastern part of the Salt Range, particularly in the neighbourhood of Dandot Colliery. They contain 66 per cent. of tricalcium phosphate but the total reserves are not sufficient to warrant extraction.

United Provinces :—Phosphatic rock, up to six inches in thickness, occurs in the Midland Estate near Mussourie and overlies the limestone. The bed was traced for a length exceeding a mile, but the quality of the rock is not constant.

Basic Slag

The basic slag produced in the manufacture of steel also contains phosphatic material. The percentage of phosphorus pentoxide in the basic slag from the furnaces of Messrs. Tata Iron and Steel Co. varies from 3 in the open-hearth slag to 6 in the Duplex plant slag. The annual outturn of these slags from this Company's works alone is about 100,000 tons, 75 per cent. of which is from Duplex plant. There is little demand for these slags and they are simply dumped away.

Nitrogen Resources

The most common mineral and chemical fertilizers are :—

(*a*) Chile Saltpetre (sodium nitrate).

(*b*) Saltpetre (Potassium nitrate).

(*c*) Ammonium sulphate,

Chile Saltpetre :—As the name indicates, it is found in large quantities in the desert region of Northern Chile. It occurs in a narrow zone trending north-south and 30 miles east of the coast. It also occurs in the adjoining portion of Bolivia. This salt, which is known as *Caliche*, forms beds having a thickness of several feet and associated with it occur gypsum, common salt, etc. As fertilizer these deposits are of great importance.

Nitre or Saltpetre :—In India, large quantities of saltpetre are manufactured by *lunias* in the United Provinces, the Punjab, and Bihar. The process is briefly as follows. Nitrous earth is collected and passed through filters. Thus saltpetre and salt, which are the two main soluble constituents of the earth, are leached out by water, which is boiled and crude saltpetre is obtained. It is subsequently refined. The author observed the making of this crude and refined saltpetre on a large scale in the districts of Muttra, Aligarh, Cawnpore, Ghazipur, Ballia, etc.

Both the nitrates are easily soluble in water and are easily assimilated by the soil and are thus at once available to plants. The repeated application of sodium nitrate to the soil for a number of years produces an alkaline residue and the soil may also become deflocculated. For this the application of sodium nitrate and ammonium sulphate is suggested in alternate years, as the latter leaves an acid residue, which will tend to neutralise the alkaline residue of sodium nitrate.

Ammonium Sulphate :—It is another important source of nitrogen and is recovered as a by-product in the manufacture of coke, etc. It is also very soluble in water and contains 20 per cent. nitrogen. When applied to the soil, it has to be converted to a nitrate by the action of nitrifying bacteria. This change, however, takes place

rapidly, and thus ammonium sulphate is also quickly available to plants. Its application is useful in rapidly-growing crops, like sugar-cane, where nitrogen happens to be deficient. This fertilizer has yielded beneficial results in crops like rice, wheat, sugar-cane, potatoes and even in plantations of tea.

Potassium Resources

Potassium, like phosphorus and nitrogen, is also an important and essential constituent for plant growth. Reserves of potash are to be found in potassium-bearing minerals like orthoclase, microcline, etc., which occur in large quantities in the pegmatites of Bihar and Rajputana. In these rocks minerals are very coarsely crystallised. Not uncommonly, pieces of these minerals attain the size of a few inches, sometimes a few feet, and it is on record that occasionally a whole quarry may be located on a single crystal. It is, therefore, not at all difficult to obtain pure material at a cheap cost. Felspars themselves are prone to alteration, but this is a very slow process. Method will have to be devised to recover potash by a cheap process.

The most important potassium fertilizers are (*i*) potassium sulphate, (*ii*) potassium chloride, (*iii*) potassium nitrate (saltpetre), (*vi*) wood ashes, (*v*) garden compost, etc. Some of these salts are found in nature, for instance, in the minerals kainite ($MgSO_4$. KCL. $3H_2O$), carnallite (KCL. Mgcl. $6H_2O$), sylvite (KCl), langbeinite (K_2SO_4. $2MgSO_4$), etc., which occur associated with the upper portions of salt deposits. They are found in Kalusz in Glacia, Poland and at Stassfurt and other places in Germany. In India they occur associated in small quantities with the salt deposits of the Cis-and the Trans-Indus regions. Although potassium-bearing minerals are found in a number of places in the Mayo Salt Mines, Khewra, but they occur only in small lenticles. Likewise, potash-bearing

minerals occur in several chambers of the Warchha Salt Mine, but the deposits are not large. In the Nurpur Mine, a bed, 6 feet in thickness, and containing about 13 per cent. of potash, was found. The potash deposits of both the Cis-Indus and the Trans-Indus regions can only be worked as a by-product of mining of salt.

The powdery salt or *reshta* which is found on the margin of the salt pans of the Sambhar lake contains more than 7 per cent. of potash.

Green glauconite sand occurs near Jubbulpore at the base of the Lametas and this mineral is a hydrated silicate of iron and potassium. It occurs in large quantities in the Chui hill and Chota Simla and Bara Simla hills.

Reference to the occurrence of saltpetre (potassium nitrate) in India has already been made. Wood ashes contain potassium carbonate, which is alkaline in reaction. In the ashes the percentage of potash varies from 5 to 6.

Calcium Resources

The fourth major element is calcium, which is abundant in the widely-distributed rock, limestone. The lime-content of most soils is low, even in its natural state. It is cheap, and a few tons per acre are only to be applied. It reduces acidity.

In India large deposits of limestone occur in various places. Extensive deposits of limestone of Lower Vindhyan age occur in the neighbourhood of Rohtasgarh in the Shahabad district of Bihar. This limestone is exploited on a large scale for the manufacture of cement. Similar limestone again occurs on a large scale in the neighbourhood of Katni, Satna, etc. As noted already, some of these limestones on analysis were found to contain a small percentage of phosphorus pentoxide.

Extensive deposits of limestone also occur in the Salt Range, where the Permo-Carboniferous and Nummulitic limestones represent almost inexhaustible supplies of the rock. At present, boulders are mainly collected from *nalas* and exported as far as Delhi. It also occurs in large quantities in the Rawalpindi and Attock districts.

In Rajputana, the States of Jodhpur, Bundi, Sirohi, etc. contain large deposits of this rock.

In Assam, large deposits of limestone (Nummulitic limestone) occur in the Khasi and Jaintia hills.

Kankar

Kankar is an impure carbonate of lime mixed with alumina and silica; a large proportion consists of carbonate of lime, ranging from about 54 to 79 per cent. or even slightly more. It is cheap and is available in most parts in the alluvial plains of India. The writer has observed the occurrence of *kankar* in the Narbada alluvium near Jubbulpore. Chemical analyses of *kankar* in some cases revealed a small proportion of phosphate.

Calcareous Marl

Similarly, calcareous marl, which may also be called block *kankar*, occurs in several parts of the Indo-Gangetic plains. It can also be utilised as a fertilizer.

Dolomite

Dolomite is a double carbonate of calcium and magnesium. Recently, an enquiry was received from the Agricultural College, Lyallpur about the occurrences of dolomite. It was to be used as a fertilizer for improving the citrus fruit. This rock is wide-spread in the country. It occurs in N.W.F.P. Near Mussoorie and Dehra Dun it occurs in inexhaustible deposits within easy reach of the railway. It again occurs on the same scale in the neigh-

bourhood of Naini Tal and the boulders of this rock have been transported by the Ballia *nadi* to Ranibagh and Kathgodam, where they are collected by local contractors to manufacture lime. Large deposits also occur in Bihar, where it is used as a flux in the smelting works of Tata Iron and Steel Company.

Gypsum

Gypsum, $CaSO_4 . 2H_2O$ is used as surface dressing for lands. It is used as a fertiliser with considerable benefit to crops. A. B. Wynne, who investigated the geology of the Trans-Indus Salt region, remarked that the crops, but particularly the wheat fields of the Kohat region flourished much better on the soils associated with the gypseous clays, as compared to other soils of the district. According to Clouston its addition of about two maunds to an acre has a remarkable effect on the monsoon crops of South Bihar. As noted already, gypsum can be used in the reclamation of *usar* lands. A brief account of the occurrence of gypsum in various parts of India is given below.

Punjab :—Commencing from the north, large quantities of gypsum occur associated with the salt deposits found in the Salt Range in the districts of Jhelum, Shahpur and Mianwali. It extends as far as Kalabagh on the Indus. The rocks, with which gypsum is associated, are known as the Saline Series. It sometimes forms beds, having a thickness of 50 feet or even more. At Khewra and other places, it is quarried. It also occurs near Dandot as also in the Makrach, Warchha and the Jansukh gorges, etc. Again large deposits occur near Daud-khel and according to E.R. Gee, any of the main deposits may contain a few million tons. Other localities, where this mineral occurs in large quantities, are in the Attock and Rawalpindi districts. It is found associated here with the Lower Chharat stage in beds having a thickness of 2 to 3 feet.

N.W.F.P. :—Likewise, large quantities of this mineral occur in the Trans-Indus Salt region in the Kohat district of the Frontier province. The mineral is associated with the upper portion of the Eocene Nummulitic rocks, and masses, measuring up to 200 feet in thickness, occur with intercalations of clay and shale. According to E. R. Gee, the resources of this mineral here are unlimited. Large reserves of this mineral occur in the Shirani country.

Kashmir :—Large deposits of this mineral also occur in Kashmir. These desposits have been formed by the alteration of pyritous limestone, and extend for 25 miles near Braripara in the district of Uri.

United Provinces :—Large deposits of gypsum occur in the United Provinces. Several deposits of this mineral occur in the neighbourhood of Sahasradhara near Dehra Dun. They occur :—(*i*) near Sahasradhara, (*ii*) near Manjhara, (*iii*) near Silkote, etc. These deposits are generally associated with dolomites and limestones, and gypsum has been formed by replacement of these rocks by the action of the sulphuretted waters and such springs are found in this vicinity even today.

Likewise, deposits of gypsum occur in the British Garhwal district and in the Tehri State near Rishi Kesh. Gypsum is also known to occur on the Nihal *nadi* between Kala-dhungi and Naini Tal in the Kumaun Himalayas. It may be added that the deposits near Sahasradhara and Rishi Kesh are not difficult of access and are already being worked to some extent. If required, these deposits could be usefully exploited for the reclamation of the *usar* lands in these provinces.

Rajputana :—Extensive deposits of gypsum occur in Rajputana. In Jodhpur State deposits of this mineral occur near Kurlo, Madpura near Kavas railway station

and Shaokar between Barmer and the Luni river. An important deposit occurs at Bhadwasi railway station, 8 miles N. N. W. of Nagaur, where a bed of this mineral, five feet in thickness, extends over an area of eight square miles. Other localities, where this mineral forms important deposits, are Barmer and Pilanwasi. The latter deposit is fairly extensive and the mineral is also of better quality.

Sind, Cutch and Kathiawar :—The Jurassic, Cretaceous and the Tertiary shales in these areas contain large quantities of this mineral. In Baluchistan, thick beds of gypsum are known to occur associated with the Eocene shales in the Bugti and other hills.

Organic Manures

Cattle Manures :—Animal manure comprises the cow and buffalo manures and also to a small extent the sheep, goat and poultry manures. But generally, it is the cattle manure which is largely used. Both the solid (dung) and the liquid (urine) manures should be used. The latter is very rich in ammonia, and thus both the solid and the liquid manures should be conserved and stored properly. Pucca pits for this purpose have been suggested as in this case the loss by leaching is prevented. But this manure is not adequate for modern requirements of intensive cultivation, and it is also not balanced in important plant foods, *viz.*, phosphorus, nitrogen and potash. It is, therefore, sometimes necessary to use mineral, chemical or other organic fertilizers.

Green Manures :—This method of green manuring consists in cultivating quick-growing, preferably leguminous crops, and then ploughing them in the land. The crops chosen for the purpose are sann-hemp (*Crotolaria juncea*), *guara* (*Cymopsis psoralioides*), *dhanchia* (*Sesbania*

aculeata). The addition of these green plants to the soil provides nitrogen and organic matter, and improve, the physical and chemical condition of the soil. These crops also help to fix nitrogen in the soil through the roots of the plants. The sann-hemp is the most popular and tested green manure of India. It has been estimated that the yield from an acre of sann-hemp is about 350-400 maunds, and this adds about a maund of nitrogen to the soil.

Oilcakes :—Various oilcakes are used as fertilizers and even for the reclamation of *usar* lands. Linseed, groundnut, sesamum, castor, rape, mustard, *neem*, *mohwa* cakes, etc., are chiefly employed. Of these *mohwa*, *neem* and castor, being non-edible, are cheaper and should be more extensively used as fertilizers. These oilcakes supply nitrogen to the soil.

In India, the value of the oilcakes as fertilizers has been tested in several provinces. In Bombay they have been found beneficial to all crops, but particularly to sugar-cane, rice and tobacco. Similarly, in Madras they have proved useful to sugar-cane and rice. Their more extensive application has been suggested. In the United Provinces, the application of oilcakes has been tried on a very extensive scale and has proved advantageous to crops like sugar-cane, wheat, rice and potatoes. About four to five maunds of oilcake per acre may be taken as an average, and it may be stated that their application has no injurious effect on soils.

It has been suggested that the export of oilseeds from this country should be checked as far as possible. It takes away the fertilizers so badly needed by the soils. The Board of Agriculture referred to this subject in 1919. The oil after pressing may be exported, but the oilcakes, required for manurial purposes and some of them for cattle feeding, should be employed wholly for these purposes.

Bone and Fish Manures

Bone-meal :—India produces large quantities of bones, which are crushed into various grades of bone-meal which is an important source of phosphates. In 1931, 21 mills for bone-crushing and manure-making existed in India, which were distributed as follows :—

Bengal	..	..	8
Madras	..	..	6
Bombay	..	..	5
U.P.	..	..	1
Hyderabad	..	..	1
			21

Bone-meal contains 27 per cent. phosphoric acid, but it is slow in action, and is therefore not readily assimilated by the soil and the crops. By treatment with sulphuric acid it is converted into readily soluble superphosphates. But a large quantity of the bones and bone-meal are exported chiefly to Belgium, France, the United Kingdom and Germany. Below are given the quantity and value of exports of bones and bone-meal for the years 1913-14, 1918-19, 1934-35 and 1935-36.

Year		Tons	Value in £
1913-14	..	105,413	522,223
1918-19	..	16,734	84,409
1934-35	..	36,474	151,771
1935-36	..	42,894	179,958

Blood-meal :—Dried blood, which is also called blood-meal, is available in fairly large quantities from the numer-ous slaughter houses in the country, and particularly from those of Bombay, Calcutta and Madras. It is also exported abroad from these ports. Likewise, animal-meal with 12 or 13 per cent. nitrogen can also be used as a fertilizer, but both blood blood-and animal-meal are largely exported abroad. It is stated that the annual exports of horn-meal are 2,000 tons valued at £ 11,845.

Fish-Manure :—Likewise, large quantities of fish manure are produced on the Malabar and Madras coasts. Small fish, sardines and adult fish are boiled and then pressed to extract fish oil. The fish manure, which is thus left, is called "guano" and when dry contains about 20 per cent. cf nitrogen and 9 per cent. of phosphoric acid. It thus makes a valuable fertilizer. Some of this fish guano is exported abroad.

Conclusion

Indian agriculture needs and deserves both official and non-official support. One of the main reasons, responsible for the low yield of crops, as compared to other countries, is the lack of adequate application of fertilizers and manures to the soils of India, some of which are almost already reaching exhaustion. It has been often advocated that these fetilizers should not be exported at cheap price abroad. With nearly 400 millions to feed, India needs them badly for their own cultivation. India is exporting large quantities of bone-meal, fish manure, etc. and the average annual value of the exports of various manures is estimated to be about Rs. 50,00,000. She thus loses valuable and important raw materials, and then has to pay a heavy price for the imported fertilizers.

Both Government and Indian industrialists should encourage the cheap manufacture of superphosphates, ammonium sulphate and potash salts, which are so vital to the improvement of Indian agriculture with poor cultivator and small holdings. With the latter, in order to raise sufficient food for the vast and dense polpulation of the country, intensive cultivation is necessary for which fertilizers are indeed indispensable. More irrigation projects and abundant suitable fertilizers are the two panacea for the main agricultural ills of this country.

CHAPTER XX

STRUCTURE OF INDIA

In this chapter the main tectonic or structural features of India are discussed briefly. Before a study of this chapter is undertaken, an acquaintance with certain terms used in this connection, is necessary.

Autochthonous Belt:—It denotes a belt of rocks which occur in their original positions and have not moved. This zone signifies the roots of a mountain.

Nappe Zone:—In contrast to the autochthonous zone it indicates the rock-sheet, which by severe earth-movements has been torn from its original home and pushed forward for many miles. Thus the rocks of the nappe zone signify a bodily movement and thrust over some other rocks. Sometimes this movement may be repeated and one nappe may rest over another, *e.g.*, the Garhwal nappe has been pushed over the Krol nappe. The Garhwal nappe is older than the Krol nappe, but, being subsequently thrust, overlies the latter.

Main Boundary Fault:—It has been observed that the Siwaliks are invariably faulted against the older rocks and this fault is a constant feature which extends from Kotli in Jammu State to the Eastern Himalayas in Assam. This fault, which has many peculiar features, is known as the Main Boundary fault. It is the reversed type of fault, along which the older rocks have been thrust over the younger ones. The forces, which have been responsible for the folding of the Himalayas, resolve themselves into tangential or horizontal thrusts, which act from opposite directions. First, the rocks are thrown into simple folds, then, into reversed folds and finally, under still greater

pressure, the middle limb breaks along which one portion is thrust over the other. In some cases the normal order of superposition on one or both sides of the fault has been reversed. According to C.S. Middlemiss, the actual angle of the thrust-plane, which marks the contact of the Murrees with the Siwaliks, is 12°-15° from the horizontal at Kotli near Jammu. Another interesting feature of this fault is that the Siwaliks never overstep this fault and in the past was generally regarded as a limit of deposition. There are other reversed faults lying to the south of the Main Boundary fault, which also represent original limits of deposition. But D.N.Wadia has stated that "though this conception still holds true to a large extent, there are exceptions here, as in other parts of the western Himalaya, *viz.*, the occurrence of patches of later Tertiary to the north of the boundary faults".

Thrusts :—Some authors include them in the category of reversed faults, while others make a class of their own. By tangential or horizontal pressure the rocks are folded. With further compression they are thrown into inverted folds until the middle limb becomes extremely thin and ultimately breaks. Owing to further pressure, the rock-sheet may sometimes be pushed forward and thus older rocks may sometimes be thrust over the younger.

Several thrusts are recognised in the older rocks of the Himalayas. The inclination of these thrusts may vary greatly within short distances. J. B. Auden has stated that the inclination of the Krol and Giri thrusts ranges a great deal; it is 20° in some places, while in others it is inverted. As mentioned above, various thrusts in the Himalayas have been recognised, *e.g.*, Main Boundary thrust, Panjal thrust, etc. Some of these are only local names of a big thrust and can be correlated, *e.g.*, the Murree thrust of Kashmir is to be correlated with the Krol thrust of the Simla region.

Structural 'Window':—This is another term which needs explanation. The structure of the Shali window near Simla has been described in detail. The older rocks (of the Chail series) were thrust over the younger strata (Shali limestone, etc.) and once completely covered them. By subsequent denudation, the cap of the older rocks is removed and thus a 'window' is formed which brings to view the previously hidden younger rocks.

Structure of the Himalayas

Commencing from the north, the Himalayan region is treated first. The arcuate disposition of the Himalayas has been mentioned in Chapter II. The convex side of the arcs faces the stable land-mass of the Peninsular region. As observed already, the Himalayas mark the site of a big geosyncline, where thick deposits ranging in age from the Cambrian to the Eocene were laid. They have been subjected to great dynamic stresses, which have been responsible for their acute folding, faulting and in some cases overthrusting. In places evidence is forthcoming that large masses, which are known as nappes, have been detached from their original positions and moved in some cases over large distances.

The four zones of the Himalayas, *viz.*, (*i*) the Outer Himalayan zone (*ii*) the Middle or the Lesser Himalayan zone, (*iii*) the Great or the Central Himalayan zone and (*iv*) the Trans-Himalayan zone have already been referred to (*vide* pp. 11-12). The first zone is built of the Eocene, Murree and the Siwalik rocks; of course the latter are predominant and extend with a few interruptions along the whole length of the Himalayas. The Murrees are absent east of Dehra Dun, while the Eocene rocks do not extend beyond Naini Tal. The Siwaliks exhibit their well-known dip-slope and escarpment feature which is indeed very remarkably displayed in the neighbourhood

of Hardwar, Jammu hills and other places. Besides, these rocks are faulted and generally their junction with the older rocks, as stated above, is marked by the Main Boundary fault.

The Middle or the Lesser Himalayan zone is composed of the Pre-Cambrian to the Tertiary strata into which different kinds of igneous rocks have intruded. They belong to the Peninsular facies and are composed of a great thickness of slates and quartzites with Gondwana and other Mesozoic rocks. In Kashmir, however, marine rocks occur. It is remarkable that this zone has a very complicated structure, showing nappes and overthrusts.

The rocks of the Great or Central Himalayan zone, on which the highest summits are located, are similar in character to those of the second zone, but gneissic and granitic rocks are more common.

The fourth zone of the Trans-Himalaya or the Tibetan zone is composed of a complete sequence of the Cambrian to Eocene strata, which was deposited in the main Himalayan geosyncline.

The Himalayan trend lines extend as far as the Karakoram and the Hindu Kush mountains and by some authorities, they are believed to be of the same age, but it has been advocated by Trinkler and De Terra that the Karakoram mountains belong to the Hercynian system of folding and are thus to be linked with the Kunlun and the Tian Shan ranges of Central Asia.

The exploration of the Himalayas has not been completed, but certain regions like the Kashmir Himalaya, Simla region and the Gaihwal Himalayas have been surveyed carefully and the main tectonic or structural elements of these regions are given below.

Kashmir Himalaya

Commencing from the north-west we begin with the Kashmir Himalaya. According to D. N. Wadia, there are three main tectonic elements.

(*i*) A wedge of the Gondwana foreland protruding northwards, which has been peneplained, and covered subsequently with the Murree sediments.

(*ii*) An autochthonous zone composed of the Carboniferous to Eocene sediments. Not infrequently, it is highly folded and inverted, and has been overthrust (the Murree thrust) against the Gondwana foreland, overlaid by the Murree sediments.

(*iii*) The nappe zone comprising two successive nappes which have travelled along the horizontal Panjal thrust and have thrust over (*i*) and (*ii*). The nappes comprise rocks of the Pre-Cambrian Salkhala Series and the Dogra Slates. Included in these are the infolded synclines of the Palæozoic and Triassic rocks building the Kashmir basin and the Shamsh Abari mountain. The Panjal (inner) and the Murree (outer) thrusts have been traced for 250 miles from the border of Hazara to Dalhousie.

This almost gives the structure of the Himalayas in general. In other regions there would be local names of the various nappes and thrusts.

Simla Region

This region has been investigated by Pilgrim and West.* (*i*) In this region the youngest Tertiaries (Siwaliks) are separated from the older Tertiaries by Main Boundary fault or boundary thrust. (*ii*) The Tertiary belt is separated from the Pre-Tertiary autochthonous belt of the Krol rocks by the Krol thrust. This has been

*Mem. G.S.I., Vol. LIII, 1928.

SECTION THROUGH THE SIMLA HIMALAYA.
BY W. D. WEST.

Horizontal scale 0 4 8 Miles
Vertical scale. 0 10,000 20,000 Feet

Fig. 18—Showing the structure of the Simla Himalaya. Note the position of the various thrusts, viz., Main Boundary fault, Krol, Giri, Chail and Jutogh thrusts. See how by the denudation of the older series, the younger rocks have been exposed in the Shali Window.

correlated with the Murree thrust of the Kashmir Himalaya. (*iii*) The Krol belt is followed by the nappe zone comprising the Jutogh and Chail Series of Pre-Cambrian age. These are bounded by the Jutogh and Giri thrusts which are comparable to the Panjal thrusts. (*iv*) The Chail thrust to the north has exposed a tectonic window of Madhan slates, Shali limestone and other Tertiary rocks near Shali peak. The significance of this 'window' has already been explained above. Intrusions of granite, *e.g.*, Chor Granite, occur in the nappe zone and farther north. (See Fig. 18.)

Garhwal Himalaya

Proceeding eastward we come to the Garhwal Himalaya. In this region (*i*) the Outer Siwalik zone is separated by the Main Boundary fault or thrust from the autochthoncus zone comprising the Simla slates, overlain by Nummulitic and younger Tertiary rocks. Its outer boundary of the autochthonous belt is marked by a reversed fault or the Main Boundary fault, while the Krol thrust marks the inner limit. (*ii*) The autochthonous Tertiary belt is overlaid by the Krol nappe, comprising the Pre-Cambrian to Tertiary rocks having almost a thickness of 20,000 feet. The Krol thrust joins with the Giri thrust in the Simla area and has been traced beyond Naini Tal. (*iii*) The Garhwal nappe has slided over the Krol nappe. It is composed of the Pre-Cambrian schists and the older Palæozoic rocks, which have undergone definitely greater metamorphism than the rocks of the Krol nappe. (*iv*) Northward lies the Central Himalayan zone which is composed of the crystalline phyllites and schists and the granitic intrusions. This zone represents the roots of the Garhwal nappe. (*v*) To the north of (*iv*) occurs the Tibetan zone which is composed of rocks comprising from the Cambrian to Cretaceous.

Nepal and Sikkim Himalaya

The Nepal Himalayas have not been explored in detail. In fact, they represent almost a blank on the map. (*a*) A thrust fault marks the junction between the Upper Siwaliks and the Nahans, while the Nahans and the Pre-Tertiaries are separated by the Main Boundary thrust. (*b*) The Pre-Tertiary rocks comprising the Krols, the Lower Palæozoic rocks and the Gondwanas, etc., are thrust over the Nahans. The Main Boundary thrust continues on to the Darjeeling region, and the Tertiary belt is again separated from the Daling schists and the Darjeeling gneisses by a thrust. (*i*) In the Sikkim Himalaya the Siwalik zone becomes narrow and is marked by two gaps. (*ii*) This is followed by the autochthonous zone comprising the Gondwanas and the Dalings. This is again narrower than the autochthonous zone on the west. (iii) The nappe zone comprising the Darjeeling, Daling and the Buxa rocks is thrust over (*ii*). The peak of Kinchinjunga occurs in the nappe zone, while Mount Everest occurs between the Central Himalayan and the Tibetan zone. The summit of Mount Everest is built of Permo-Carboniferous limestone, which is metamorphosed, while the northern flanks are composed of Permian to Jurassic sediments. The intensity of metamorphism decreases gradually as we proceed towards the north.

The Eastern Himalayas have not been fully explored, but it is surmised that they represent an extension of the constitution and structure observed in the Sikkim Himalaya. The changes observed in the trend of the mountains have already been referred to in Chapter II, p. 9. Likewise, the syntaxes of the Himalayas have been discussed on pp. 20-22.

Thus, the main features of the Himalayan structure or tectonics briefly are, that in the south there is the (*i*) Ter-

tiary belt and sometimes, particularly in the north-west, the junction of the Upper and the Lower Tertiaries is marked by a thrust known as Main Boundary fault. In the Kashmir region is the protrusion of the Gondwana foreland, overlaid by the Murree rocks. (*ii*) It is followed by the autochthonous belt, which is generally composed of the Pre-Cambrian with some Palæozic strata and is bounded by thrusts. (*iii*) This is capped by one or more nappes, usually two, which are again demarcated by thrusts.

Indo-Gangetic Plains

The structure of the original depression of these plains, their depth, subsequent filling and isostatic compensation have been discussed already in Chapter XVI. The relationships of the Indo-Gangetic trough with the Himalayas and the Deccan tableland are shown in Fig. 19.

Peninsular India

The structure of the Peninsular region is somewhat simple. At the conclusion of the Dharwar period, there were huge diastrophic movements, which brought about the acute folding and contortion of the Dharwar sediments. The Purana rocks, *viz.*, the Cuddapah, and particularly the Vindhyans, do not reveal that they were disturbed by severe earth-movements. On the other hand the Vindhyan rocks are either almost horizontal or show only gentle dips. It is only in Rajputana that they have undergone folding and faulting proving that Peninsular India is certainly a more stable land-mass, as compared to Rajputana. But as noted already, there was some igneous activity and also orogenic activity, particularly in Rajputana, during the Vindhyan period. Until the Upper Carboniferous times,there was a hiatus and then fresh-waterdeposits were laid in some of the regions, which were let down in

the older rocks between vertical fissures of post-Gondwana age. Towards the close of the Gondwana Era, there was some igneous activity which, as noted already, manifested

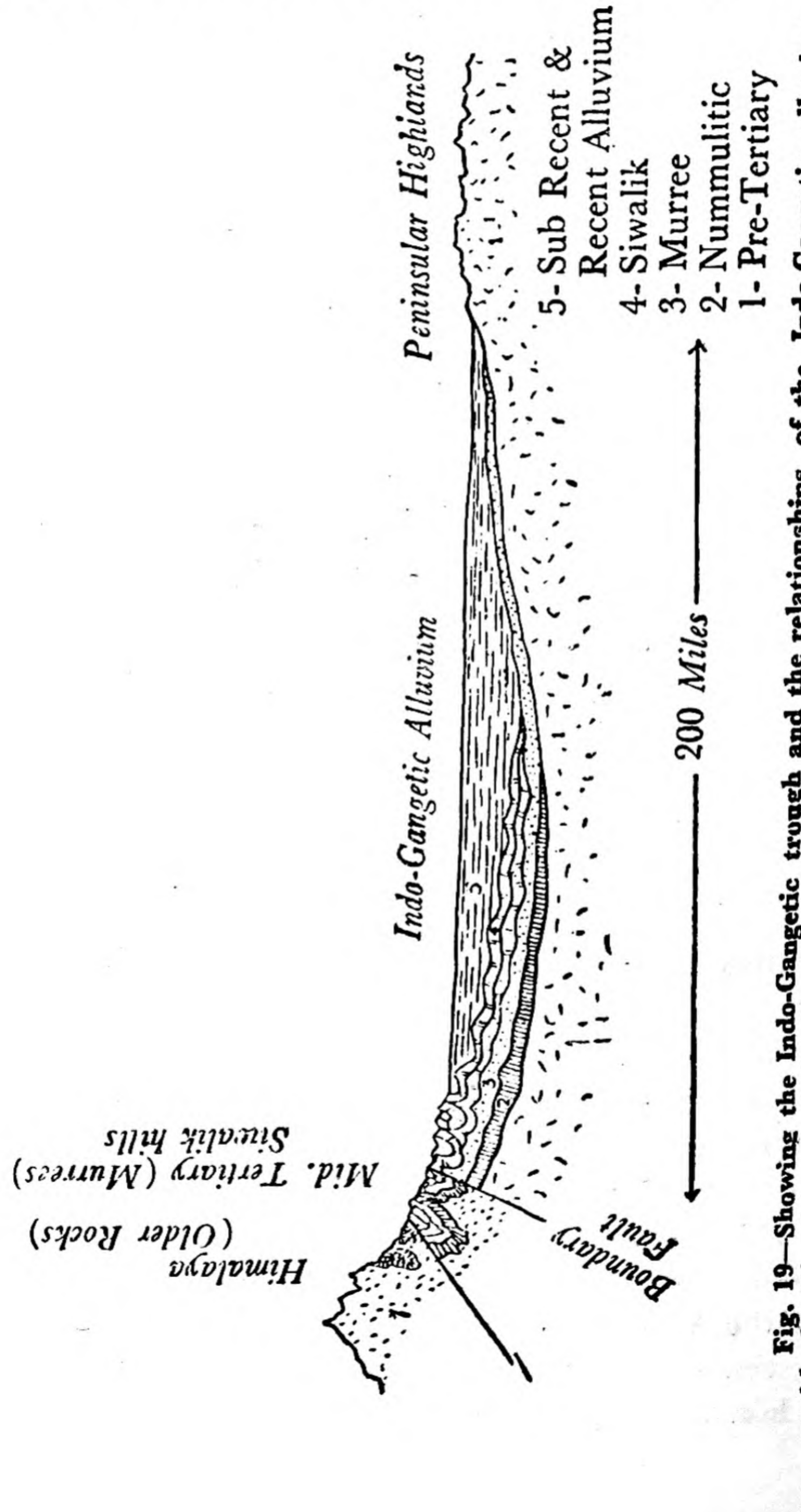


Fig. 19—Showing the Indo-Gangetic trough and the relationships of the Indo-Gangetic alluvium with the Himalayas and the Deccan table land. (D.N. Wadia).

itself in the Rajmahal hills and as dyke-rocks in the eastern part of the Bengal coalfields. It has been emphasized already that, towards the close of the Mesozcic and the beginning of the Tertiary Era, huge volcanic eruptions repeatly flooded the denuded floor of the Archæan and other rocks, particularly in Western and Central India. They obliterated entirely all the previous tectonic and other features of this part of the Deccan and built a lava plateau on them. Subsequent to this volcanic activity the western coast of India was faulted with the development of its pesent, regular coast-line. As stated elsewhere, the east coast of India resumed almost its present outline in the Jurassic period, while the western coast acquired its present shape in the early Tertiary times.

Tectonics of the Aravallis

A brief account of the Aravallis has been given already in Chapters II and XVI. Here it is proposed to give a brief account of their structure. These mountains extend in a N.E.—S.W. direction from the plains of Gujarat in the south to Delhi in the north, a length of more than 400 miles. These are the visible limits of these mountains, and it is considered that they originally extended considerably farther to the north and to the south. In the north, the syntaxis of the Himalayas in the north-west is considered by some authorities to be due to the extension of the Aravallis round which the Himalayas had to make a geniculate bend. Mushketov, however, is of the opinion that they have not only affected the trend of the Himlayas, but also of the Pamir and the Ferghana range. Towards the south it is considered that they extended on to the Laccadives and on the sub-marine ridge these coral islands have been built. At the south-western extremity lies the peak of Mount Abu, 5,650 feet above sea level. There are several other peaks, whose elevation exceeds 4,000

Heaven

feet above sea level. According to A. M. Heron they "are probably the oldest folded mountains on the globe which still remain as a range".

The Aravalli range was folded in pre-Vindhyan times and the Vindhyan sediments were derived by their denudation. In fact, it separated the sedimentation in the two Vindhyan areas. As even the youngest Vindhyan rocks are folded, it is apparent that dynamic stresses were active in post-Vindhyan times also.

In the extreme south-east of Rajputana, the sandstones and shales, which build the western end of the Vindhyan plateau of Central India, are faulted against the gneissic rocks of the Mewar plain. This fault was styled by Heron as the Great Boundary Fault of Rajputana. It is noteworthy that in this region the Vindhyans have been folded and faulted, and the fault lines run parallel to the Great Boundary Fault. This feature, as noted above, is an exception, as elsewhere the Vindhyans are almost horizontal.

The country is composed of detached prominent groups of ridges, which run parallel. The ridges have very steep slopes and absolutely flat tops. These level summits indicate the height of the peneplain, which has been subsequently dissected into these separate ridges. Excepting Mount Abu, which is composed of granite, no peak is found to be above this level. In the middle of the range, north-west of Udaipur, the level of the peneplain is about 4,000 feet above sea level, but it gradually falls along the axis of the range. In the hills in Alwar, its elevation is 1,800—2,200 feet and south of Delhi, it is only 1,000 feet above sea level. It has been concluded that this peneplanation stage was attained in the Mesozoic times, but before the Lower Cretaceous.

After the peneplanation, the mountain has undergone warping to attain the present elevation. In the centre, the maximum elevation is 3,500 feet, while at the ends it is only 300 to 400 feet. Thus, the mountain underwent rejuvenation in the Mesozoic period. It has been advanced that this rejuvenation and the Great Boundary fault may have been contemporaneous.

It has been stated above that the submarine ridge, which extends to the Laccadive islands, is a submerged portion of the Aravallis, which foundered, probably after the volcanic eruptions of the Deccan Trap when the west coast of India was faulted and the link with Africa was broken.

According to L. L. Fermor, the Aravalli region is a horst; on the east it is bounded by the Great Boundary Fault of Rajputana and on the west by a hypothetical fault, which, explorers like A. M. Heron, Coulson and P. K. Ghosh have not been able to confirm in the field.

To recapitulate, the sequence of events in the building and structure of the Aravallis is as follows:—

(1) The Bundelkhand gneiss was formed, which represents mainly some varieties of granite.

(2) Sediments, equivalent of the Dharwars of the Peninsula, were deposited.

(3) These were folded before the Vindhyan times and the Aravalli range was formed.

(4) During the Vindhyan times sedimentation took place in the eastern and western areas separated by the Aravalli range.

(5) During post-Vindhyan times even the youngest Vindhyan sediments were folded.

(6) The Aravallis were peneplaned by the Mesozoic times.

(7) The rejuvenation of the peneplain occurred in pre-Tertiary time with the development of the Great Boundary fault.

(8) In the post-Deccan Trap period, *i.e.*, in the Tertiary times, the southern extension of the Aravallis sank probably at the time of disruption of the Gondwanaland and the faulting of the west coast of India.

Structural Phases :—Briefly, the important structural phases of India comprise the following :—

(*i*) First phase was at the end of the Dharwar period or the Archæan Era, which was responsible for the folding, contortion, etc., of the Dharwar rocks. The Aravallis were also uplifted about the same time.

(*ii*) The second phase was during the post-Vindhyan time, when the Aravallis were further uplifted. As noted above, the youngest Vindhyan rocks are involved in this upheaval.

(*iii*) There was a minor phase at the end of the Upper Carboniferous when there was a short break in the sedimentation in the Himalayan geosyncline.

(*iv*) The fourth important phase was towards the close of the Mesozoic or the beginning of the Tertiary Era.

(*a*) It resulted in the breaking of the Gondwanaland, faulting of the west coast of India and the formation of the Arabian sea. Post-Gondwana faults also originated about this time.

(*b*) The deposits laid in the Himalayan geosyncline were uplifted in post-Nummulitic to Oligocene period to build the Himalayan chain.

(*c*) The Indo-Gangetic trough also originated about the same time.

(*v*) In post-Miocene time, the Himalayas were further uplifted. It was at this time that the important nappe zones of the Himalayas, *e.g.*, the Kashmir nappe, the Simla nappes, the Krol and Garhwal nappes were formed.

(*vi*) At the end of the Pliocene or the Tertiary Era, the Himalayas had their third phase of upheaval, when the Upper Siwaliks were folded.

(*vii*) In Sub-Recent times, another series of movements disturbed the Karewas and the Pleistocene boulder conglomerates of various regions.

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